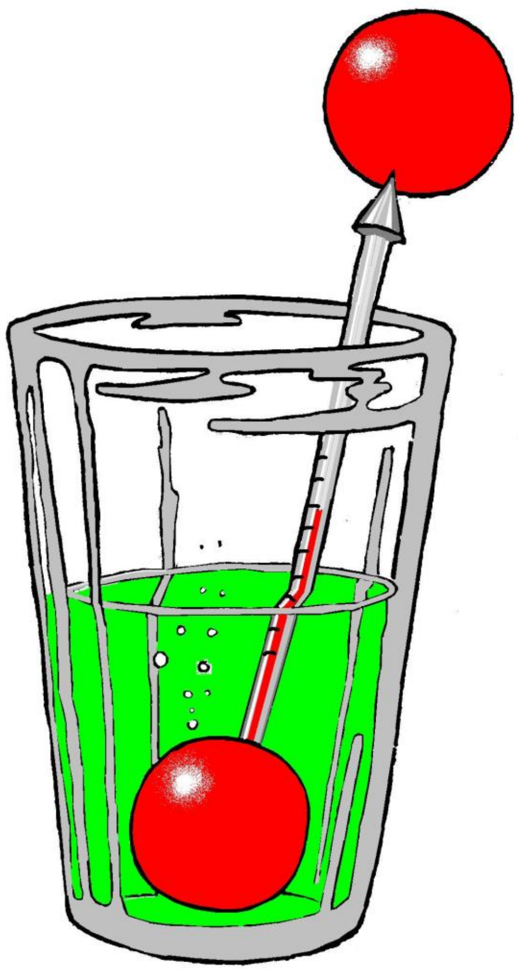
TRIZ POWER TOOLS

Skill # 4 Idealizing Informing Functions

December 2012 Edition



Removing, Replacing and Adding Informing Functions

TRIZ Power Tools

Skill #4 Idealizing Informing Features

December 2012 Edition

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(Table of Contents)

Introduction 1

L1-Idealize Informing Functions 3

L2-Ideal Final Observer—Doesn't Need to Know 4

L2-Ideal Subject 5

L3-(Ideal Subject-No Measurement)—Measurement Not Required 6

L3-(Ideal Subject-No Measurement)—Non-Existent Subject 8

L3-(Ideal Subject-No Measurement)—Direct Acting Sensors 9

L3-(Ideal Subject-No Measurement)—Subject Comes Pre-Measured 12

L3-(Ideal Subject-Least Measurement)—Detect or Measure the Minimum Part or Constituents 13

L3-(Ideal Subject-Natural Groupings)—Multiple Subject Elements 14

L2-Ideal Measurement 17

L3-Describe the Measurement in a Variety of Ways 18

L3-What is the Ideal Accuracy? 20

L3-What is the Ideal Sequence of Measurement? 20

L3-What is the Ideal Duration of Measurement? 21

L3-What is the Ideal Duty Cycle of Measurement? 22

L3-What is the Ideal Adjustability and Continuity of Adjustment? 23

L3-When Should Measurement Be Excluded? 24

L2-Potential Physical Phenomena 25

L3-(Evolutionary History)—Search for Existing Products or Services 27

L3-(Evolutionary History)—Patent and Literature Search 29

L3-(Evolutionary History)—Identify Competitive Alternatives 32

L3-(Evolutionary History)—Evolution of Field Phenomena 33

L3-(Evolutionary History)—Disruptive Technologies 35

L3-(Evolutionary History)—Determine the System Maturity from Patents 37
L3-(Switch Phenomena?)—Is it Time for a Switch? 38
L3-(Potential Phenomena)—Secondary Phenomena 40
L3-(Potential Phenomena)—Derivative Detection 42
L3-(Potential Phenomena)—Already Poorly Performed by Native Fields 43
L3-(Potential Phenomena)—Analogous Measurement 44
L3-(Potential Phenomena)—Measure a Copy or Facsimile 46
L3-(Potential Phenomena)—Discrete Detection 47
L3-(Potential Phenomena)—Field Markers 48
L3-(Potential Phenomena)—Substance Markers 55
L3-(Potential Phenomena)—Multiplied Subject Elements 60
L3-(Potential Phenomena)—Resonance 62
L3-(Potential Phenomena)—Natural Analogous Observer 64
L3-(Potential Phenomena)—Library of Scientific Effects 65
L3-(Potential Phenomena)—Search Patents 66
L3-(Potential Phenomena)—Intelligent Little People 72
L3-(Potential Phenomena)—Summarize the Potential Phenomena 73
L2-Observer Resources 75
L3-Abundant Native Fields 76
L3-Grocery List of Adjacent Elements 77
L3-Grocery List of Cheap Abundant Substances 78
L3-Nearby Similar Measurement Devices 79
L3-Simplified Copy of the Current Measurement Device 80
L3-Merge with the Super-System 80
L3-Summarize the Observer Resources 81
L2-Ideal Observer 83
L3-Filter for the Ideal Observer 84
L3-Commercial Measurement Systems and Subsystems 89
L3-Use Known Disruptive Technology 91

L3-Hybrid Combination of Physical Phenomena 92
L3-Decide the Measurement System 94

Introduction

(If you are reading the PDF format—navigate the algorithms with the "Bookmarks" to the left. L1, L2, L3 correspond to levels of the algorithm. The levels are hierarchical; you can go as deeply as required to resolve your problem. Lower levels (L1, L2) have consolidated methods. If you are using the book then use the Table of Contents for the Algorithm)

All of the books in the TRIZ Power Tools book series are designed to be used as algorithms. Each algorithm can be as detailed or simple as required. This is done by going up or down in the hierarchy of the process steps. The top level (L1) of the bookmarks is the highest level. If more detail is required, the user can go to deeper levels (L2 and L3).

Where the Book Materials Come From

Much of the material for this book was inspired by the thought leaders referenced. The original intent was to codify the insights of these thought leaders, but the exercise of codification ultimately led to the synthesis of other experimental processes. This is because codification required recognizing patterns between similar tools. Once this was achieved, the various tools were grouped with key decisions. Decisions require and create information which flows to the next decisions. Patterns and gaps became visible during this formative process. Experimental methods were inserted into the gaps. The proof of these experimental methods is whether they actually help the reader to identify product or process characteristics that will delight the market.

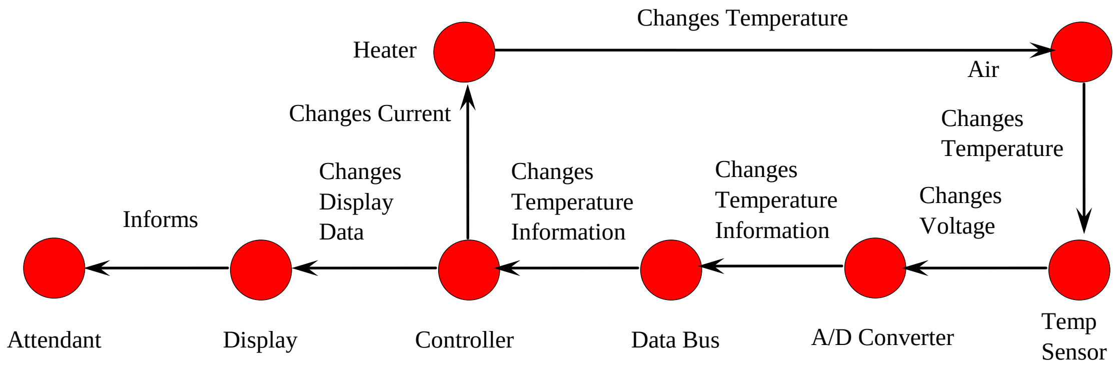
Prerequisite Knowledge: Working with Functions

If you have not read the TRIZ Power Tools Series Book about the skill of working with functions, please do this before reading this book.

Informing Functions (Measurement and Detection)

Informing functions have to do with measurement or detection. Measurement is actually a subclass of useful functions, but there are additional considerations that we need to take into account. First, the subject is the object being measured or detected. It is the tool of the useful function. It modifies or informs the product or observer. This seems backwards from what we would normally say in English. "The thermometer measures the water temperature". From the English, it would appear that the thermometer is modifying the water by measuring it. In reality, the water modifies the thermometer. It changes the temperature of the thermometer which, in turn, informs or modifies the observer. This is a classic "confusing function". The direction of the function is always from the subject to the observer. For the rest of this book, we will refer to the tool as the subject and the product as the observer.

Another difference between informing functions and useful functions is that someplace in the system is a known "observer". Unlike the typical useful function, where the only required part of the function is the product, there is a required and known observer. This puts constraints on the search for an ideal subject, informing modification, physical phenomenon and observer. Describing this in functional terms, there is a functional chain between the object that needs to be measured and the human observer that needs to be informed. For any given system, certain elements in that chain are known. For example, consider the climate control for a large building.



This system will likely have a large number of sensors measuring such things as temperature and humidity. Each sensor must eventually give a voltage signal which is measured by an analog to digital converter and placed on a data bus. The data bus then changes digital attributes in the controller which manipulates the data and displays the results to a display screen where an attendant then can be informed and respond to what is displayed. The controller also affects a heater which changes the temperature of the air. Notice that the role of subject and observer is constantly changing as we move along the chain. Each observer becomes a subject for the next observer in the chain. Depending upon the part of this chain that we have control over, we will need to make decisions concerning the modifications, physical phenomena and observers that will deliver the functions. In some cases, we may have control over the entire chain, in others; we may have control over one link. The point is that for every measurement system, there are known elements that must be linked together. This is different than useful functions in which only a final result in the product is required.

The system that we have shown is the extreme case, but also serves to show that there is usually a chain of transformations that must occur between the main subject that we are trying to measure and the observer or observers. Each transformation has its burdens. We would like to have as few transformations as possible to get the job done. We would ideally like the requirement to measure the air temperature to go away entirely. If there were only one temperature to measure then it would be more ideal for the air to directly inform the attendant. As mentioned, in a long chain of transformations, each observer becomes the subject for the next measurement transformation in the system.

In the following sections, we will explore how functions in the measurement chain are idealized. The sequence is different than used in idealizing useful functions, even though measurement and detection is also a type of useful function.

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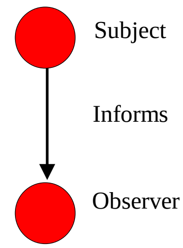
L1-Idealize Informing Functions



The first step to idealizing any function is the chain is to first idealize the observer in that function. We want to know why measurement is important to the observer. If the observer does not need to know the measured attribute then it may not be necessary for measurement to occur.

If measurement is required, then we want to identify the ideal subject to be measured. Perhaps it doesn't need to be measured. This allows for the most ideal systems to be considered first. A measurement system that does not require measurement is more ideal than a system where the measurement tool is idealized.

The final step is to decide how the detection or measurement will occur. In this case, the most important consideration is the chain of physical phenomena which includes actual objects that will deliver the physical phenomena. Notice that we have allowed for a chain of transformations. Ideally, we want as few transformations as possible, but we still have to allow for a chain of physical phenomena in order to be consistent with the subject and the observer.

L1-Method

Step 1: Brainstorm the ideal observer: Find out why the observer needs to know. Remove the need for measurement. Find out why the measurement is required and remove the reason. Consider pre-measurement.

Step 2: Brainstorm the ideal modification: Look for the ideal timing so that measurement is much easier.

Step 3: Brainstorm the ideal chain of physical phenomenon: Consider using field or substance markets in, on or around the subjects. Consider measuring a secondary effect. Consider measuring the derivative or integral of the parameter. Consider measuring resonance. Consider measuring a copy[1] *instead. Consider using a different measurement phenomenon that does not require the offending parts. Consider a chain of physical phenomena which lead from the subject to the observer.*

Step 4: Brainstorm the Ideal Objects of the Chain: Look for ways to incorporate measurement tools that already exist. Look for ways to incorporate measuring tools from the super system.

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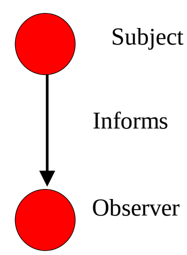
1 Inventive Principle #26—Copying: A simplified and inexpensive copy should be used in place of a fragile original or an object that is inconvenient to operate. If a visible optical copy is used, replace it with an infrared or ultraviolet copies. Replace an object (or system of objects) with their optical image. The image can then be reduced or enlarged. Genrich Altshuller, The Innovation Algorithm page 288.

L2-Ideal Final Observer—Doesn't Need to Know

Up to this point, we have taken for granted that the observer is a required system object. We cannot afford to take this for granted. If we have any control on the system, we must challenge the requirement for the observer. The ideal final observer is one that does not require the measurement to occur. Measurement brings many burdens to the system. Sensors provide auxiliary functions to systems which do not directly modify the system product. Consequently, they have lower functional ranking or value in the system. Paradoxically, sensors are often one of the most expensive elements in the system. If the need for measurement is removed, then we can usually remove a lot of system elements.

Is there something about the observer that makes measurement or detection unnecessary? Why does the observer want to know the attributes of the measured object? The reason can be disappointing. This is especially true in human systems. Take the example where an obsessive employer wants to monitor his employees. While this may seem extreme, it is nevertheless a very useful way to look at a situation from a new point of view. In order to accomplish this result a slight modification of the product is usually required.

L2-Method



Step 1: Identify the "required" observer and the required subject that must be measured or detected. If the system is technical, you may need to decide where you have control over the system and where you do not.

Step 2: Why does the observer require informing? Follow this reasoning back through the causal relationships. If a Causal analysis Diagram is being used, it is easier to follow the chain of reasoning back to the problems that the measurement function helps to resolve. At this point, we are looking for a reason that has to do with the observer. What characteristics of the observer make this function necessary?

Step 3: A change to an object in the system (often the observer) removes the requirement for the observer to be informed.

L2-Ideal Subject

The Ideal Subject Doesn't Require Measurement

There is something about the subject that makes measurement or detection unnecessary. As mentioned earlier, there are usually many burdens associated with measurement. The typical measurement system has many interlinking elements that wind their way back to the observer. If measurement is not required, then we can eliminate many system parts.

The Ideal Subject Comes in Natural Groups

If we have decided that the measurement is necessary, then the most ideal subject is a group. If the group is a natural group, then it is even more ideal. Many subjects come in natural groups. If we can perform the function on all of them, preferably at the same time, then this can make the system less complex.

Measuring and detecting objects may not be required if the objects to be measured are not required in the first place. If we can find a way to discard the subject, there is no need to measure them.

L2-Method

Step 1: Brainstorm ways that the measurement is not required. Usually, the measurement is required because of some failing of the system. Look for ways to improve the failings so that there is no need for measurement.

Step 2: Look for ways to remove the subject from the system. There may be poor reasons that the subject exists. Remove these reasons.

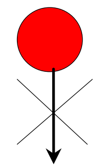
Step 3: Look for ways to remove active feedback systems with direct acting sensors. Remember that these sensors need to operate near the critical point of some physical phenomenon.

Step 4: Consider ways that the subject comes pre-measured so that there is no need to measure it.

Step 5: Look for the minimum part of the subject that needs to be measured.

Step 6: Consider measuring natural groupings at once by measuring the average.

L3-(Ideal Subject-No Measurement)—Measurement Not Required



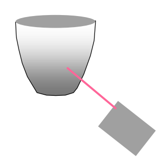
There is something about the subject that makes measurement or detection unnecessary.[2] All measurement functions can be thought of in a remedial or preventative context. This may not seem intuitive at first, but consider the following. Why do we measure the temperature of air in a room? It is because the temperature tends to go out of the comfortable zone. It is not doing its job! If it were doing its job, the air would remain the correct temperature all of the time without external action. While this may seem excessive, it is nevertheless a very useful way to look at a situation from a new point of view. In order to accomplish this result a modification of some object in the system is often required.

Method

Step1: Why is the subject being measured? Is detecting or measurement required in preparation for fixing, preventing or countering something? Follow this reasoning back through the causal relationships. If a Causal analysis Diagram is being used, it is easier to follow the chain of reasoning back to the problems that the measurement function helps to resolve. (Remember that this is usually done by considering existence of elements).

Step 2: A change to an object in the system (often the object that we are serving) removes the requirement for the main function and hence the objects that deliver the function. In other words, if something did its job better, our system wouldn't be needed. What modification to the subject or other element in the system would make it so that measurement is not required?

Example—Vacuum Crucible



The temperature of a crucible in a vacuum furnace is constantly measured.

Step1: Why is the subject being measured? Is detecting or measurement required in preparation for fixing, preventing or countering something? Follow this reasoning back through the causal relationships. If a Causal analysis Diagram is being used, it is easier to follow the chain of reasoning back to the problems that the measurement function helps to resolve. (Remember that this is usually done by considering existence of elements).

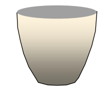
The temperature is being measured to ensure that the operator knows when the crucible is about to melt.

Step 2: A change to an object in the system (often the object that we are serving) removes the requirement for the main function and hence the objects that deliver the function. In other words, if something did its job better, our system wouldn't be needed. What

2 STANDARD 4-1-1. If a problem involves detection or measurement, it is proposed to change the problem in such a way, so that there should be no need to perform detection or measurement at all. Example: To prevent a permanent electric motor from overheating, its temperature is measured by a temperature sensor. If to make the poles of the motor of an alloy with a Curie point equal to the critical value of the temperature, the motor will stop itself.

modification to the subject or other element in the system would make it so that measurement is not required?

The crucible is made of a material with a high enough melting temperature that it cannot melt. Temperature measurement is no longer required.



Example—Measuring Job Performance

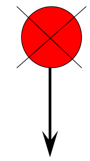
Step1: Why is the subject being measured? Is detecting or measurement required in preparation for fixing, preventing or countering something? Follow this reasoning back through the causal relationships. If a Causal analysis Diagram is being used, it is easier to follow the chain of reasoning back to the problems that the measurement function helps to resolve. (Remember that this is usually done by considering existence of elements).

Measurement of job performance is “required” because workers do not always perform in a manner that is “best” for the company. This is a remedial function. Also, it is “required” so that the company may know how to recompense the employee. This is also a preventative action to keep the employee from leaving. Both remedial and preventative functions are prime candidates for removal. By taking it for granted that these remedial or preventative actions are required, companies spend a great deal of time and money on this process.

Step 2: A change to an object in the system (often the object that we are serving) removes the requirement for the main function and hence the objects that deliver the function. In other words, if something did its job better, our system wouldn’t be needed. What modification to the subject or other element in the system would make it so that measurement is not required?

In this case, we might consider changing the system of how the company “contracts” with the employee or allowing employees to identify areas that they could better serve the company with their particular talents. It may be possible to hire employees that have already been through the gauntlet and have proven themselves to be worthy of not monitoring. In some highly developed countries, salary increases are automatic and dependent upon competitive pay for that position.

L3-(Ideal Subject-No Measurement)—Non-Existent Subject



The ideal subject does not require the measurement. There are a variety of reasons that measurement may not be required. If the element isn't required in the system or doesn't even exist, then there is no requirement for measurement.

Method

Step 1: Is the subject ever Harmful, Waste? Yes

Step 2: Eliminate Subject. No way found

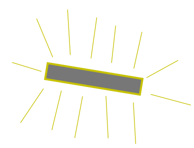
Step 3: Eliminate Source. No way found

Step 4: Eliminate Path. No way found

Step 5: The Waste becomes useful and thus is eliminated by its usefulness.

Example—Nuclear Waste

Nuclear Waste and its storage medium must be monitored.



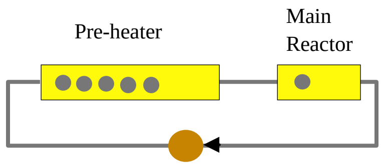
Step 1: Is the subject ever Harmful, Waste? Yes

Step 2: Eliminate Subject. No way found

Step 3: Eliminate Source. No way found

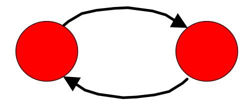
Step 4: Eliminate Path. No way found

Step 5: The Waste becomes useful and thus is eliminated by its usefulness.



The Nuclear Waste becomes a pre-heater. As the pre-heater grows, the main reactor material is reduced.

L3-(Ideal Subject-No Measurement)—Direct Acting Sensors



The highest form of control is passive control. Systems ideally use one field for operation and control. Consider consolidating the sensing, control and actuating elements into one element that does all of these functions. What this means is that the substances involved are capable of sensing a field and then use the field to create muscle force to actuate. Fields that actuate and signal are generally towards the middle of the Table of Fields (Appendix: Thermal, magnetic, vibration, etc).

The system is usually operated close to tripping a critical point. For reference, here are some examples of critical points: A critical point is a region of operation where the properties of an object change abruptly. Most physical phenomena can be tailored to operate in the around a critical point. Efficiency of system operation can be increased by operating near critical points.[3] This often involves the use of Phase Transitions[4]. The boiling or melting points of a substance are critical points.

For humans, the critical points are associated with human senses. Note that the table to the right contains human thresholds.

Operating near critical points allows for direct acting elements. For passive control[5] [6], we demand that the sensor use the same fields for sense and modulation (the subject is a combined sensor and modulating element).

Critical Points	Human
Sheer Strength	Temperature threshold
Ultimate Strength	Pressure threshold
Tip Angle	Auditory threshold
Static Friction	Olfactory threshold
Adhesive Failure point	Personal space violation
Zero Buoyancy	Speed threshold
Triple point	Altitude threshold
Surface Tension	Visual thresholds
Resonant Frequency	Startling point
Spark point	Discomfort (A pattern or perception that something is out of place)
Freezing point	Equilibrium threshold
Boiling point	
Curie temperature	

3 STANDARD 5-4-1. If an object is to be alternating between different physical states, the transition is performed by the object itself using reversible physical transformations, e.g. phase transitions, ionization-recombination, dissociation-association, etc. Note: A dynamic balance providing for the process self-adjustment or stabilization may be maintained in the dual-phase state.

STANDARD 5-4-2. If it is necessary to obtain a strong effect at the system's output, given a weak effect at the input, the transformer substance is placed to a condition close to critical. The energy is stored in the substance, and the input signal acts as a "trigger".

4 Inventive Principle #36—Phase Transition: Using the phenomena of phase change (i.e., a change in volume, the liberation or absorption of heat, etc.). Genrich Altshuller, The Innovation Algorithm page 289.

5 Inventive Principle #25—Self-service: An object must service itself and carry-out supplementary and repair operations. Make use of waste material and energy. Genrich Altshuller, The Innovation Algorithm page 288.

6 Use of critical points is an extension of Standard 1-2-5. There are many physical phenomena that exhibit critical points. Operation about these critical points allows for large forces to be created which, in turn, can be used for actuation. STANDARD 1-2-5. If it is necessary to decompose a SFM with a magnetic field, the problem is solved by using physical effects, which are capable of “switching off” ferromagnetic properties of substances, e.g. by demagnetizing during an impact or during heating above Curie point. Notes: The magnetic field may appear at the right moment if a system of magnets compensating the effect of each other's field is used. When one of the magnets is demagnetized, a magnetic field arises in the system. Example: During welding, it is difficult to insert a ferromagnetic powder in the welding zone: an electromagnetic field of a welding current makes the particles move away from the welding zone. It is proposed to heat the powders above the Curie point to make them non-magnetic.

Method

Step1: Identify the fields associated with the parameter of the subject that is being sensed.

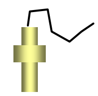
Step 2: Identify a physical phenomenon which uses this same field for sense and actuation and which reacts to the parameter change that we are trying to measure.

Step 3: Identify the critical point of the physical phenomena at which small changes in input cause large changes in output. (Or large changes in input create small changes in output). Move this critical point to the desired control point. Now, small changes in input cause large changes in output.

Step 4: Identify how crossing this critical point can be used to both sense and control.

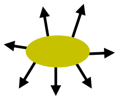
Example—Fluid Temperature Feedback

Consider a control system that measures the temperature of a fluid and then actuates a fluid closure element.



Step1: Identify the fields associated with the parameter of the subject that is being sensed.

The field is a thermal field

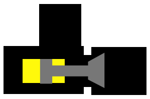


Step 2: Identify a physical phenomenon which uses this same field for sense and actuation and which reacts to the parameter change that we are trying to measure.

Expansion during Phase Change

Step 3: Identify the critical point of the physical phenomena at which small changes in input cause large changes in output. (Or large changes in input create small changes in output). Move this critical point to the desired control point. Now, small changes in input cause large changes in output.

Melting Point

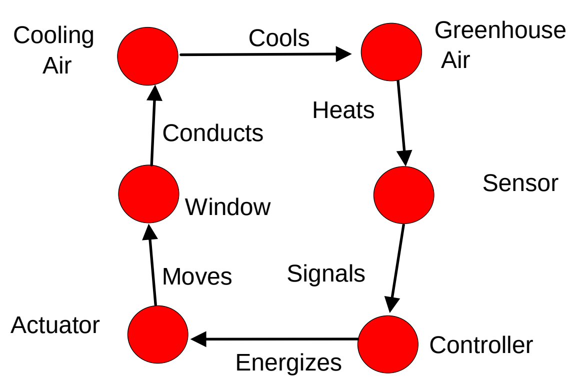


Step 4: Identify how crossing this critical point can be used to both sense and control.

Expansion upon melting provides muscle to move closure element.

Example—Greenhouse Temperature Control

Consider the example of a cooling system for a greenhouse. Use of passive control will invariably lead to fewer parts. The existing system uses a sensor, controller and actuator to open the window when needed.



Step1: Identify the fields associated with the parameter of the subject that is being sensed.

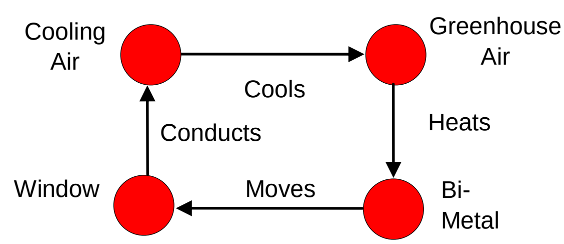
A Temperature field.

Step 2: Identify a physical phenomenon which uses this same field for sense and actuation and which reacts to the parameter change that we are trying to measure.

We would like the window to open itself when needed. With a Bi-Metal Actuator (two metals with different thermal coefficients of expansion), we still use the same field (heat) and use it to open the window directly.

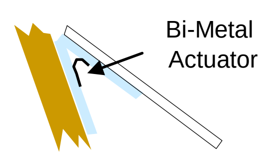
Step 3: Identify the critical point of the physical phenomena at which small changes in input cause large changes in output. (Or large changes in input create small changes in output). Move this critical point to the desired control point. Now, small changes in input cause large changes in output.

In this case there is no intrinsic "critical point" such as the boiling point or the Curie point. We need to create a critical point by establishing a spring preload in the bi-metallic strip. Normally the bi-metal strip pushes hard against the window holding it closed.

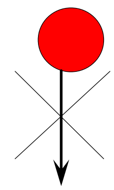


Step 4: Identify how crossing this critical point can be used to both sense and control.

When the temperature increases enough to release the preload, the window begins to open. This pretension in the spring can be set to an established level to create a critical point. Now we have a system that is more reliable, has fewer parts and costs less.



L3-(Ideal Subject-No Measurement)—Subject Comes Pre-Measured



The Subject does not require detection because the detection is already incorporated. Can the subject be apportioned in such a way that the required properties are already known or pre-measured? This principle is an extension of the principle of Prior Action[7] where the action of measuring and using the measured substance or field is broken down into measurement and action with the measurement performed prior to being required.

Method

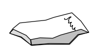
Step 1: For substances, identify a way to make the substance pre measured.

Step 2: For measurement of fields, make the source of the fields come in discrete forms.

Examples—Substances and Fields

Step 1: For substances, identify a way to make the substance pre measured.

Medication—Pills

Food—Packets 

Tubes—Pre-fabricated diameters (very accurate)

Step 2: For measurement of fields, make the source of the fields come in discrete forms.

Following are several examples.

Sound or Vibration— Set frequencies (resonance) and duration

Light—Set frequencies or duration

Buoyancy—discrete volumes

Pressures—Saturated liquid gas phase gives one pressure

Temperature—Saturated liquid-gas phase gives off pressure

Current—Use of current driver

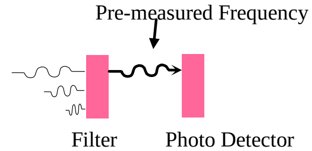
Example—Detection of Astronomical Phenomena

Step 1: For substances, identify a way to make the substance pre measured.

Not applicable since this is the measurement of fields.

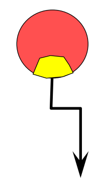
7 Inventive Principle #10—Prior Action: Perform required changes to an object completely or partially in advance. Place objects in advance so that they can go into action immediately from the most convenient location. Genrich Altshuller, The Innovation Algorithm page 287.

Step 2: For measurement of fields, make the source of the fields come in discrete forms.



Astronomical objects give off many frequencies of light. These frequencies can often be separated into frequency "bands" by optical gratings. Expensive detectors can sense a variety of frequencies, but large sections of the sky need to be surveyed. How can the frequencies be pre-measured? By use of an optical filter, the light can be filtered to specific frequencies which show up as anomalies or can be discretely detected with an alarm.

L3-(Ideal Subject-Least Measurement)—Detect or Measure the Minimum Part or Constituents



Detecting or measuring a parameter of a system composed of a variety of elements allows for the possibility of simplifying by measuring the parameters for only part of the system. It is natural to directly measure the properties of the direct elements. An alternative method is to measure the properties of the constituents or derivatives of the constituents to determine the properties of the whole.

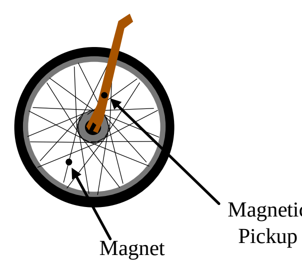
Method

Step 1: If the subject is a single element, what minimum part of the subject must be detected?

Step 2: If the subject is composed of multiple elements, identify parts of the system that could be measured, rather than measuring the whole system.

Example—Bicycle Speedometer

How can the speed of a bicycle be determined?



Step 1: If the subject is a single element, what minimum part of the subject must be detected?

Detect the revolution of part of the wheel rather than the whole bicycle

Step 2: If the subject is composed of multiple elements, identify parts of the system that could be measured, rather than measuring the whole system.

Example—Corrosion Measurement

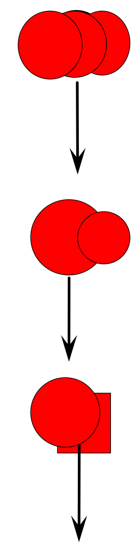
How can corrosion of metallic samples be detected and measured?

Step 1: If the subject is a single element, what minimum part of the subject must be detected?

Since we know the base materials and the acids being used, we probably have a list of corrosion byproducts. It may be possible to detect only part of the byproducts. For instance, if one of the potential corrosion products is iron oxide then we might try to measure the oxygen in the sample. There are existing methods to detect chemical compounds on the surface of objects which only look for a part of the constituents.

Step 2: If the subject is composed of multiple elements, identify parts of the system that could be measured, rather than measuring the whole system.

L3-(Ideal Subject-Natural Groupings)—Multiple Subject Elements



The seed for this tool comes from the standards involving multiple system elements.[8] [9] [10][11] However, there is a twist to the idea. Simply increasing the number of subject elements that are measured/detected is definitely an improvement over performing the functions on single product elements, but it is yet more useful when the subjects come in natural groupings. Such groupings often are dictated by nature or commonly accepted manufacturing conditions.

In the Case of multiple and identical subject elements, it is often more ideal or easier to detect the average parameter of many objects than it is to detect the properties of a single object.[12] This is almost always true when detecting the properties of small things such as particles, molecules, atoms. This is especially true if the subjects come in natural groupings. In this case, we are treating all of the objects that are being measured and looking primarily for the statistics of the group.

In the case of biased subjects, it may be more ideal to measure a natural group of these all at once.

In the case of completely different subjects that come in natural groupings, it may be more ideal to measure all of them together.

---

8 STANDARD 3-1-1. System efficiency at any stage of its evolution can be improved by combining the system with another system (or systems) to form a bi- or poly-system. Notes: For a simple formation of bi- and poly-systems, two and more components are combined. Components to be combined may be substances, fields, substance- field pairs and whole SFMs. Example: To process sides of thin glass plates, several plates are put together to prevent glass from breaking.

9 STANDARD 3-1-2. Efficiency of bi- and poly-systems can be improved by developing links between system elements. Notes: Links between elements of a bi- and poly-system may be made either more rigid or more dynamic. Example: To synchronize a process of lifting a very heavy part by three cranes, it is proposed to use a rigid triangle synchronizing the cranes moving parts.

10 Inventive Principle #7—Nesting (Matrioshka): One object is placed inside another. That object is placed inside a third one. And so on. An object passes through a cavity in another object. Genrich Altshuller, The Innovation Algorithm page 287.

11 STANDARD 3-1-3. Efficiency of bi- and poly-systems can be improved by increasing the difference between system components. The following line of evolution is recommended: similar components (pencils of the same color) –->components with biased characteristics (pencils of different colors) –->different components (set of drawing instruments) –->combinations of the "component + component with opposite function" (pencil with rubber)

12 STANDARD 4-5-1. Efficiency of a measuring system at any stage of its evolution can be improved by forming bi- or poly-system. Notes: To form bi- and poly-systems, two or more components are combined. The components to be combined may be substances, fields, substance-field pairs and SFMs. Example: It is difficult to accurately measure the temperature of a small beetle. However, if there are many beetles put together, the temperature can be measured easily.

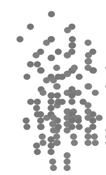
Method

Step 1: Do the subjects that need the same measurement come in natural batches or groups? Do they come in large groups or in groups that are hard to separate? The subjects may be identical, similar in some aspect or completely different. The important question is whether they require the same measurement.

Step 2: Is it more ideal (or easier) to detect the group simultaneously? For instance, is it advantageous to know the average value as opposed to individual values of measurement? Measuring the subjects as a group makes it easier and gives an average value which may be more ideal in some situations.

Example—Measuring the Temperature of an Insect

It is desirable to understand the metabolic rate of insects. In order to do this, we would like to measure their temperature compared to the ambient environment.



Step 1: Do the subjects that need the same measurement come in natural batches or groups? Do they come in large groups or in groups that are hard to separate? The subjects may be identical, similar in some aspect or completely different. The important question is whether they require the same measurement.

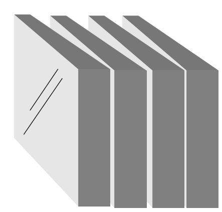
While the insects do not come in natural groups but rather arbitrary swarms, they are small, making them hard to separate. This makes this situation a likely situation for measuring in groups.

Step 2: Is it more ideal (or easier) to detect the group simultaneously? For instance, is it advantageous to know the average value as opposed to individual values of measurement? Measuring the subjects as a group makes it easier and gives an average value which may be more ideal in some situations.

In this case, it is more advantageous to measure the average temperature of a swarm.

Example—Measurement of Glass Thickness

Consider the measurement of the thickness of each piece of glass in a stack of glass. The glass to be measured has a variety of thickness within a narrow range.



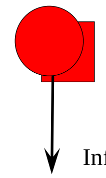
Step 1: Do the subjects that need the same measurement come in natural batches or groups?. Do they come in large groups or in groups that are hard to separate? The subjects may be identical, similar in some aspect or completely different. The important question is whether they require the same measurement.

The glass comes as a stack of plates that have a slight variation in thickness. For our application, the variety of thicknesses is detrimental.

Step 2: Is it more ideal (or easier) to detect the group simultaneously? For instance, is it advantageous to know the average value as opposed to individual values of measurement? Measuring the subjects as a group makes it easier and gives an average value which may be more ideal in some situations.

The net thickness, coupled with the number of sheets will help us to understand whether the individual plates have a wide variation.

Example—Weighing Fruit and Vegetables



Consider automatic checkout of fruits and vegetables in a grocery store. Each fruit or vegetable comes in a variety of weights. Yet, the speed of weighing and assigning costs must be done rapidly.

Step 1: Do the subjects that need the same measurement come in natural batches or groups. Do they come in large groups or in groups that are hard to separate? The subjects may be identical, similar in some aspect or completely different. The important question is whether they require the same measurement.

The fruits and vegetables come in natural groups, but they are quite different from each other. However, they all require the same measurement of weight.

Step 2: Is it more ideal (or easier) to detect the group simultaneously? For instance, is it advantageous to know the average value as opposed to individual values of measurement? Measuring the subjects as a group makes it easier and gives an average value which may be more ideal in some situations.

An automatic checkout would be greatly enhanced if it could detect the presence of a large variety of items at the same time.

L2-Ideal Measurement

Set the Bar for How Well the Modification must be Performed

We just asked ourselves, in the section on idealizing useful functions, what the ideal level of the function was. If I could snap my fingers and make things magically happen, how much do I want to modify or control the subject? Here we ask a similar question. If I could snap my fingers, how would I like the function to be performed? How well, how long, etc. It is important to note that insights derived at this stage have the ability to influence each other. Consequently, the tools in this section may not be followed linearly. It may be necessary to jump back and forth between tools. Conclusions gained during one activity may be upset by insights gained in other activities.

L2-Method

Step 1: Describe the measurement or detection in a variety of ways

Step 2: What is the ideal accuracy?

Step 3: What is the ideal sequence of measurement? Within all the other processes, what is the best time to perform the measurement?

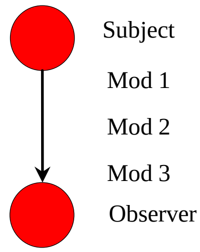
Step 4: What is the ideal duration of measurement? What is the longest time allowed to measure the system?

Step 5: What is the ideal duty cycle of measurement? How often does it need to be done really?

Step 6: What is the ideal adjustability and continuity of adjustment of the measuring

Step 7: When should the measurement be excluded? When is it harmful or dangerous? When is it wasteful?

L3-Describe the Measurement in a Variety of Ways



After focusing on the ideal observer and the ideal subject, we focus on the ideal modification. We ask: What do we really want to have happen and what are the attributes of the ideal informing? While informing functions are useful, the ideal modification for informing functions (measurement and detection) has to be thought of differently than useful functions. Since the subject that is being measured and the observer are both known, this can be confusing. What does it mean to inform ideally? We are setting the stage to think differently about the measurement.

According to the laws of system evolution, we would like detection to occur with as few energy transformations as possible. Often, there is a multi-step process that occurs between the subject and the observer. The subject being measured changes something else which changes something else which changes something else which then informs the user.

Now, how do we describe this in the most ideal way possible? We would like as few transformations as possible. What are ideal final results? In some situations, the most ideal measurement is that the observer merely "looks" (smells, feels or hears) and all required information is transferred. In another situation where control is required, the observer may be a system that detects a voltage. The ideal in this case is that the change in the subject being measured directly changes the voltage of the system.

It is not enough to describe this in only one way. Each way may lead to a different physical phenomenon to accomplish the function (depending on abundance of system resources).

What would I want to happen if I could do it magically by snapping my fingers?

Method

Step 1: Identify the subject and its attribute that is being measured.

Step 2: Identify the "observer". This may be a human or system which collects information for logging or control.

Step 3: Begin with the assumption that the modification will occur directly between the subject being measured and the observer. If this is not possible, we will come back and allow another transformation to occur.

Step 4: Consider the observer. What attribute do we want to change in the observer? If the observer is human, we need to pick a sense that we want to affect. If the observer is a device, then we need to decide which device attributes we would like to change (voltage, current, etc.).

Step 6: Work backward by imagining several ideal final states. Using the longhand form of the modification, consider different ways to describe the modification. Consider moving from the macro world to the micro world (atomic level and beyond).

Example—Detecting Fan Speed

Step 1: Identify the subject and its attribute that is being measured.

The subject being measured is the fan and its rotational speed.

Step 2: Identify the "observer". This may be a human or system which collects information for logging or control.

The observer is a human observer.

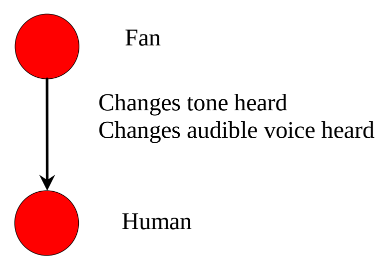
Step 3: Begin with the assumption that the modification will occur directly between the subject being measured and the observer. If this is not possible, we will come back and allow another transformation to occur.

The fan must directly inform the user of its speed.

Step 4: Consider the observer. What attribute do we want to change in the observer? If the observer is human, we need to pick a sense that we want to affect. If the observer is a device, then we need to decide which device attributes we would like to change (voltage, current, etc.).

In this case, the attribute that I want to change is the sense of hearing.

Step 6: Work backward by imagining several ideal final states. Using the longhand form of the modification, consider different ways to describe the modification. Consider moving from the macro world to the micro world (atomic level and beyond).



In this case, the human directly hears the fan and knows its speed by detecting and translating the audible sounds given off by the fan.

Example—Detecting Corrosion

Step 1: Identify the subject and its attribute that is being measured.

The subject is the corrosion and the level of corrosion.

Step 2: Identify the "observer". This may be a human or system which collects information for logging or control.

The observer is a voltage sensing device.

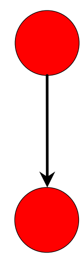
Step 3: Begin with the assumption that the modification will occur directly between the subject being measured and the observer. If this is not possible, we will come back and allow another transformation to occur.

The corrosion directly informs the observer which is a voltage measurement device. We would like as few transformations as possible to achieve this voltage measurement. As we shall see, some of the means for measuring corrosion can give a current which directly gives a voltage.

Step 4: Consider the observer. What attribute do we want to change in the observer? If the observer is human, we need to pick a sense that we want to affect. If the observer is a device, then we need to decide which device attributes we would like to change (voltage, current, etc.).

We want to directly affect the voltage.

Step 6: Work backward by imagining several ideal final states. Using the longhand form of the modification, consider different ways to describe the modification. Consider moving from the macro world to the micro world (atomic level and beyond).



L3-What is the Ideal Accuracy?

Determine the actual level of the ideal informing. This level usually involves a metric. As we begin to adjust the levels of the informing, we start to chip away at psychological inertia. We gain insights.

Method

Step 1: If I could snap my fingers, what would the ideal level of informing be? What is the ideal accuracy?

Example—Detecting Corrosion

Step 1: If I could snap my fingers, what would the ideal level of informing be? What is the ideal level of accuracy?

The unit of measurement is probably mass of corrosion per mass of base material per unit of time. For example, grams of rust per grams of iron per hour. The accuracy should probably be measured as a percent. For example the rust is 2 grams per 100 grams of iron per hour +/- 3% of the 2 grams measured. Notice that this makes the requirement that the corrosion directly informs the observer much more difficult because the human ability to discern small changes is not very good. We may need to come back and change to a more indirect measure later.

L3-What is the Ideal Sequence of Measurement?

This method comes from considerations of harmonizing functions[13] or actions in a system.

> The law of harmonizing the rhythms of parts of the system: An essential condition for the living viability in principle of a technical system is the harmonization of the rhythms (frequencies of vibration, periodicity) of all parts of the system.

13 Creativity as an Exact Science—the Theory of the Solution of Inventive Problems, G.S Altshuller, Gordon and Breach, page 226.

Considering the ideal sequence will continue to give us more insights into the ideal informing. A powerful method for investigating this is the process map. This can be accomplished in a variety of ways, including a storyboard or simply words in sequence. However it is done, it is nice to show the possibility of functions performed in parallel as this will be one of the considerations that we make.

Method

Step 1: Create a process map of the sequence of functions. Informing functions show up as blocks in the process map. It is preferable, but not absolutely necessary that functional language be used.

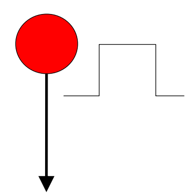
Step 2: Consider performing the informing function in different sequences. Move it earlier or later than currently performed. Try moving it so far forward that it is no longer during the normal process sequence. Consider moving it so far backward that it is no longer part of the ordinary sequence.

Step 3: Can the function be performed in parallel with other functions?

Step 4: If necessary, break down sections of the map into finer detail.

Step 5: Can the modification be broken into two (or more) stages? Does this allow for parallel processes to accomplish the main function, or does it allow for a more optimum sequencing of functions?

L3-What is the Ideal Duration of Measurement?



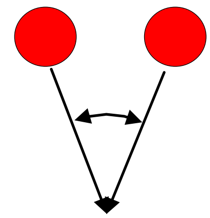
The ideal sequence is strongly influenced by the duration of the function. Likewise, duration of the function is strongly influenced by the sequence of the function.

Method

Step 1: If the informing modification were performed very rapidly, would other harmful functions be precluded?

Step 2: How much time do we have after it is normally performed that it would be allowable to continue performing the function? If the modification were performed very slowly (hours, days, weeks, months, years) would this be harmful or could this actually help in the performance of other functions?

L3-What is the Ideal Duty Cycle of Measurement?



Ideality requires that all objects perform as many functions as possible, as much of the time as possible. Systems that idle use valuable resources without doing anything. Consequently, it is important to consider idealizing the function by requiring the system to work all of the time[14].

Method

Step 1: Are there opportunities for the system to run all the time? Is this even desirable considering the current subject? Ideally, objects in the system will be at full capacity

Step 2: Are there other objects in the job that require the same informing function? Should the informing function be reframed to consider these other objects?

Step 3: Should the informing modification be performed along the entire path, both coming and going? This usually applies to machines which have repetitive motions. Should dummy runs and downtimes be allowed?

Example—Measuring Corrosion

Step 1: Are there opportunities for the system to run all the time? Is this even desirable considering the current subject? Ideally, objects in the system will be at full capacity

The ideal duty cycle is that the measurement should be able to precede from one cube to the next without delay.

Step 2: Are there other objects in the job that require the same informing function? Should the informing function be reframed to consider these other objects?

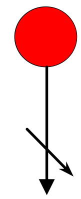
This is not necessary.

Step 3: Should the informing modification be performed along the entire path, both coming and going? This usually applies to machines which have repetitive motions. Should dummy runs and downtimes be allowed?

This is not necessary.

14 Inventive Principle #20—Continuity of Useful Action: Carry out an action without a break. All parts of the objects should constantly operated at full capacity. Remove idle and intermediate motion. Replace "back-and-forth" motion with a rotating one. Genrich Altshuller, The Innovation Algorithm page 288.

L3-What is the Ideal Adjustability and Continuity of Adjustment?



Lines of evolution suggest that the control of functions become more and more adjustable[15]. At first, the process is fixed. Next it becomes adjustable to at least discrete levels. Next, the adjustment must become continuous. Next, some form of control scheme is used to adjust the function for changing conditions. The first form of control often turns the function on or off. This is often referred to as "bang-bang" control. The next form of control is referred to as open-loop control. This means that a change is sensed somewhere and the mechanism that controls the function is given a set command that puts the output in the required range. The next form of control uses feedback[16] which continuously or discretely controls the function. Each level of adjustment and control increase the complexity of the system. It is important here to not go overboard in assigning an ideal level of adjustability. We can over-constrain the system. This sounds too much like a compromise, but here we will consider only an acceptable level of adjustment that will allow this system to operate for a long time without change.

Method

Step 1: Consider different and perhaps extreme operating environments. Decide whether or not the informing function must be capable of adapting to these different environments

Step 2: Consider adjustability to a variety of measured objects. How much variation can we tolerate? Consider biased objects (objects which are of the same type, but have some differences in an important attribute like nails of various sizes or roses of different shades). Consider objects with much greater differences such as the range of edible plants.

Step 3: What granularity of adjustment is necessary? Can the adjustment be discrete? If so, what is the discrete step size?

Step 5: Does the adjustment need to be continuous or should it require continuous feedback?

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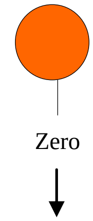
15 Inventive Principle #15—Dynamicity: Characteristics of an object or outside environment, must be altered to provide optimal performance at each stage of an operation. If an object is immobile, make it mobile. Make it interchangeable. Divide an object into elements capable of changing their position relative to each other. Genrich Altshuller, The Innovation Algorithm page 288.

16 Inventive Principle #23—Feedback: Introduce feedback. If feedback already exists, change it. Genrich Altshuller, The Innovation Algorithm page 288.

L3-When Should Measurement Be Excluded?



The Zero Function[17] is the intended absence of a function under certain conditions. We should have full control over the function when its existence would be dangerous or otherwise harmful.

Method

Step 1: Identify times when the informing functions are harmful.

Step 2: Consider providing the zero function and means for detecting and controlling the informing function during these times.

17 Greg Yezersky, General Theory of Innovation Feb 2006

L2-Potential Physical Phenomena

Once we know the measurement to deliver, we are prepared to talk about how we are going to deliver the measurement. Informing functions have to be treated a little different than other useful functions. The measurement subject (tool) modifies the observer (product). This modification occurs through the use of a physical phenomenon which makes the measured parameter of the subject detectable and ultimately measurable.

A Definition of Physical Phenomena

The term "Physical phenomenon" is a human abstract of fields and substances arranged in special architectures that do something recognizable. Because it is a human abstract, there are certain to be ambiguities related to this definition. Fortunately, most people recognize and relate to the word phenomena. The study of physics is primarily the study of physical phenomena. This is fortunate because it helps the user to understand what phenomena can be used for and how to calculate the effects of the associated parameters. For the purposes of this book, we will enlarge this definition to include "scientific effects" a common term in the TRIZ world.

In the well-known TRIZ approach of substance-field analysis, one of the important members of any interaction triad is a field. This can leave us with the mistaken belief that all interactions are the result of single fields. When we enlarge our view of how functions are delivered to considering physical phenomena, we realize that many interactions are the result of combinations of fields. It is common that more than one field is involved in a physical phenomenon. Consequently, we will replace the concept fields delivering functions to phenomena delivering functions.

Evolutionary History

In order to make a decision on whether to change to a new phenomenon, we need to study the evolutionary history of the function in question. What phenomena have been used and what improvements have occurred over time. This can be done by looking at existing products, patents, phenomena from competitive products, evolution of field phenomena and physical phenomena from disruptive technologies.

Competitive alternatives are any systems that can potentially compete with the system that you are simplifying or creating. A newspaper is competition for the television. Car or truck transportation is competition for airline travel. We will consider phenomena which are associated with these alternatives.

Disruptive technologies are usually associated with products or services using physical phenomena that are developed for other markets. When these products or services begin to draw away your customers, we refer to this as disruptive technologies. Moving to this new technology can be very disruptive to our own business as well as other competitors.

The Decision to Change to a New Phenomenon

Once we understand the evolutionary history, we are prepared to decide whether the time is right to change to a new physical phenomenon.

The decision of whether or not to change to a new physical phenomenon is often ignored or taken for granted. The typical action is to continue using the familiar phenomenon. Whenever we ignore or take for granted, we are assuming and therefore subject to psychological inertia. We may not recognize that there are more ideal physical phenomena that can be used to deliver our modification to the tool. We may be ignoring free resources in the environment or in the job that can be used to simplify the system.

On the other hand, new physical phenomena can lead to a lot of headaches. Whenever you change to a new physical phenomenon, there are many new "unknowns". (You might be lucky because you already have experience the new phenomenon. This makes the possibility of bridging to the new phenomenon much easier). Remember that the new product or service must compete with one that has been polished for many years. The bar is quite high. If it is not time to change, then there is no need to look further for potential physical phenomena.

Potential Phenomena

If it is time to change to a new phenomenon then we need to understand the options. Some phenomena will be more ideal due to the abundance of fields and substances or because of the ease of manipulating the fields. A number of approaches are provided to create options.

The observer and the physical phenomenon always come together, but for our purposes we will consider the phenomena separately as potential physical phenomena. In effect, we are sensitizing our minds for the next step in which we consider the resources which will become the observer. Armed with the knowledge of what is possible, it will be easier to identify the value of a resource when we see it. In other words, the decision of which physical phenomenon to use will come after seeing the available observer resources.

There are many avenues for identifying potential physical phenomena. Certain phenomena are already used to perform the function. Others need to be transported from other industries. While the phenomena that we discover may not be new in the sense that we have discovered them from research, they may be "new" to the industry.

Some of the phenomena that we may consider in this stage may seem a little wild or too weak to perform the function. Remember that such weak phenomena can often be boosted in latter stages of the algorithm. Therefore, it is important to keep an open mind to the possibilities.

L2-Method

Step 1: Search for existing products on the internet and in stores. Also look for competing products that people would use if nothing was available.

Step 2: Study the history of the measurement including patents. Note the evolution of fields used. What would be the next logical step?

Step 3: Decide whether it is time for a new phenomenon to use for measuring.

Step 4: Look for new ways to perform the measurement. Especially consider using secondary phenomena and measuring a copy. If possible, use the Library of Scientific Effects.

L3-(Evolutionary History)—Search for Existing Products or Services

The first task in determining the physical phenomena and scientific effects used for measurement and detection is to see what is available on the internet and in stores, etc. This gives us a look at the technologies that have been commercially viable so far. This does not give an exhaustive look at what is possible. Also, if we are not in the business of creating new measuring devices, it may be in our best interest to look around and see what is out there already. If existing products or services are sufficient then we may not need to go through the next steps.

Method

Step 1: Use an internet search-engine to find existing products and services. Refine the search by noting and using nomenclature and names that are common to the industry.

Step 2: Look for inexpensive competitive alternatives that could be used if the other existing products were not available.

Step3: If possible, go to a store that would sell offerings that deliver the required modification.

Step 4: Note brands and producers. Do the producers sell more than one offering? Who are the main producers?

Step 5: Look for product trends.

Step 6: What do advertisements and labels claim?

Step 7: Are the existing products and services sufficient?

Example—Measuring Corrosion Rate

What are the commercial means for measuring corrosion of metallic samples?

Step 1: Use an internet search-engine to find existing products and services. Refine the search by noting and using nomenclature and names that are common to the industry.

Most corrosion testing occurs according to industry standards. The author does not have access to these standards but was able to identify some corrosion testing equipment. Thomas register showed 12 companies that sold corrosion testing equipment. Many of these produced equipment which would require multiple costly measurements to get corrosion rate such as digital imaging and ultrasonic thickness measurement. Further searching produced other possibilities:

http://www.bio-logic.info/potentiostat/notes/20120604%20-%20Application%20note%2039-2.pdf (This detector measures the “noise resistance” between two electrodes. Noise resistance is calculated from an instantaneous voltage difference between the electrodes and the instantaneous current between the electrode. The noise resistance is equal to the standard deviation of the instantaneous voltage divided by the standard deviation of the instantaneous current. It was interesting to the author that noise could be used to measure corrosion. This becomes increasingly evident as we realize the dynamic nature of corrosion. The flow of ions comes in fits and spurts in pits and blemishes on the surface. It also became evident from reading this material that the electrochemical noise changes over time in a way that suggests that the corrosion increases asymptotically with time. In other words, it settles to a level after several hours. This means that rapid measurements may need to be correlated with long-term measurements in order to be accurate and satisfy our need to measure the corrosion very rapidly.

http://shop.sailboatowners.com/prod.php?4207/GalvanAlert%26trade%3B+Shore+Power+Corrosion+Detector (This detector measures the current from galvanic corrosion caused by shore-based power hookups to boats by monitoring reverse polarity and stray currents through the ground wire—it costs about $152)

http://www.alibaba.com/product-gs/458679915/Digital_Intelligent_Eddy_Current_Testing_equipment.html?s=p (This uses alternating currents from 10 to 10MHz to determine thicknesses of corrosion. It costs about $5000)

http://www.corrinstruments.com/ins/field_monitor.html (Measures corrosion potential--Prices not given)

http://www.cosasco.com/corrosion-monitoring-instrument.html (This company uses replaceable probes that can substitute as coupons. They have the advantage of allowing quick measurements, which gives us the idea that our samples could be made into replacement electrodes and tested rapidly by these devices.)

http://www.stoprust.com/index.htm (Uses electro-chemical probes to determine deep structure corrosion).

http://www.cosasco.com/laboratory-environment-probe.html#configurator (Measures corrosion in industrial production settings and then logs or relays the information. The author was unable to determine what phenomenon was used to measure corrosion).

It should be noted that finding corrosion testing equipment on the internet was not as easy as the author originally assumed. No attempts were made to network with suppliers which might have yielded more results.

Step 2: Look for inexpensive competitive alternatives that could be used if the other existing products were not available.

http://compare.ebay.com/like/230531911798?var=lv&ltyp=AllFixedPriceItemTypes&var=sbar (This is a corrosion assessment hammer—The user bangs on the car to detect corrosion. The sound properties are changed by the corrosion. Apparently the user strikes automobile bodies and listens for the characteristic dull thud of corrosion.)

Step3: If possible, go to a store that would sell offerings that deliver the required modification.

Not performed due to lack of time.

Step 4: Look for product trends.

Most of the products which produced corrosion rate information appeared to use electro-chemical or weight loss testing. One used eddy currents. The industry is primarily driven by corrosion testing which follows international standards and by in-place testing of support structures. One article noted that ASTM has held a number of symposia on the subject of electro-chemical techniques and found them to be quite accurate. The implication is that what normally takes weeks to test can take seconds or minutes and are highly accurate. This gives us a lot of confidence that the measurements can be made very rapidly and accurately.

Step 5: What do advertisements and labels claim?

The advertisements claim that the methods used are very accurate. Unfortunately, little is said about the speed of measurements. The speed of measurements is noted by subject matter experts.

Step 6: Are the existing products and services sufficient?

For the purposes of measuring corrosion accurately, the products and services are probably quite accurate and would save a great deal of time and money. For the purposes of exposing the reader to a wider variety of methods, we will continue with the following methods.

L3-(Evolutionary History)—Patent and Literature Search

Knowing the history[18] of a system helps in understanding the main evolutionary trends. Each system has a main evolutionary tendency. The tendency of a system to stall along this evolutionary path is largely a function of the technical problems that directly conflict with this evolutionary tendency. You have already conducted a patent search within your industry so you have a lot of information about the history. This step can take time, but the information is extremely valuable from the viewpoint of continued steps. The inventor is becoming a true expert in this field.

Method

Step 1: From patents and literature, study the history of the functions that are typically involved in the job. What functions have been added over time? What main physical parameters have improved?

Step 2: From patents and literature, study the history of the technologies (physical phenomena) that typically deliver these functions. How have these technologies changed? What physical phenomena and scientific effects have been used to deliver the functions?

Step 3: Summarize the history.

Example—Measurement of Corrosion

Step 1: From patents and literature, study the history of the technologies (physical phenomena) used for detection. How have these technologies changed? What physical phenomena and scientific effects have been used to deliver the functions?

18 The Innovation Algorithm by Genrich Altshuller page 215—While Altshuller's life was a study of the history of systems, this particular chapter shows the various stages of a technology. Altshuller made it a point to take an existing system and determine the evolutionary history of that particular system.

- From http://www.corrosion-club.com/historyelectrochem.htm Electrochemical Corrosion Monitoring - Historical Items: 1942 Hickling - Potentiostat: The term "potentiostat" introduced by A. Hickling, who was also the designer of such an historical electronic model. An article on the web site www.bio-logic.fr also credits Hickling with the invention of the three electrode potentiostat (facilitating automatic control of the cell potential) - "genius idea" and principle still in use today. Potentiostats became widely used as laboratory corrosion measurement instruments in the 1960's. Source: H.S. Isaacs: "Aspects of Corrosion from the ECS Publications", Journal of the Electrochemical Society", Vol. 149, No.12, pp.S85-S87, 2002. (An ECS Centennial Series Article). 1957 M. Stern and A.L. Geary: Measurement of general corrosion rate by inverse of polarization resistance, from potential and current measurements near the free corrosion potential. Widely used in d.c. electrochemical corrosion monitoring instruments. 1960's Epelboin: Development of electrochemical impedance spectroscopy (EIS), a.c. corrosion measurement tools. 1968: Warren P. Iverson—Measurement of voltage transients (fluctuations) in corroding metals and alloys. "... he (Warren Iverson) published a short article in the Journal of the Electrochemical Society that many still quote as the first paper in electrochemical noise ..." Source: F. Huet, A. Bautista and U. Bertocci: "Listening to Corrosion", The Electrochemical Society Interface, Winter 2001, pp.40-43.
- 1956—US2947679—corrosion rate is measured by a correlation between the corrosion current and the current necessary to lower the relative potential of the corroded metal a certain amount. It is interesting that instead of measuring the amount of corrosion, this method measures the corrosion rate which is an instantaneous measurement that could speed up the process of corrosion measurement for our example. The method is straight-forward and allows for a nearly direct voltage measurement.
- 1956—US2856495—In order to determine the corrosion of pipes without disassembly, the resistance of a wire inside of the pipe is measured. The metal wire represents the metal of the pipe and is long and thin to allow for the maximum change in resistance due to the corrosion. This could also be used in our example if the capsules were no longer capsules but were very long and very thin wires that would rapidly register a resistance change to the acid.
- 1959—US3069332—Direct measurement of the corrosion current. This is related to US2947679 above. This provides a faster was to capture a voltage representing the corrosion current.
- 1964—US3337440—Similar to US2947679 except that it discusses measuring the corrosion current when surrounded by jet fuel, etc.
- 1965—US3684679—Similar to US2947679
- 1966-US3449232--Similar to US2947679 except it provides a means of measuring the current in more difficult situations where the corrosion is caused by a drop of water in an oxygen environment. The cathode is then formed at the interface between the drop, the oxygen and the corroded metal.
- 1966—US3539808—Irradiate sample with beta nuclear radiation and then measure back scatter and correlate with thickness of corrosion. This measurement will require several transformations to get voltage.
- 1970—US3609549—Similar to US2856495 in that the corrosion is indirectly measured by noting changes in resistance. This invention seeks to solve the problem of heating of the specimen by the resistance measurement system.
- 1971—US3748247—Similar to the 1956 patent US2947679. This invention seeks to make a convenient probe.
- 1972—US3821641—Introduces oscillating current probes and a balancing circuit to keep the current amplitudes constant. The means to keep the current amplitude constant is then measured to derive the rate of corrosion.
- 1974—US3947329—Similar to the 1956 patent US2947679 but extends the method to high rates of corrosion by imposing electrical conditions for short periods and then watching how the system reacts.
- 1977—US4130464—This is a fundamentally new method which measures the rate of decay of the potential of the electric double layer. A charge is driven into the electric double layer and the potential is reduced by the corrosion.

- 1979—US4238298—Apply alternating currents between test plates and measure the alternating current impedance. The corrosion rate is a function of the alternating current impedance.
- 1983—US$575678—The corrosion rate is measured by measuring the low frequency noise voltage between two electrodes immersed in the corrosive environment. The voltage is averaged to give the corrosion rate.
- 1987—US4800165—is essentially the same as US4238298 applied to large structures in a corrosive environment.
- 1987—US4758312—an electrochemically active material is placed into the liquid corroding environment having a reduction potential more positive than the corroded material. The material is then removed from the environment following the reaction and analyzed. The resulting analysis is correlated to the actual corrosion of the material.
- 1990—US4006786—is essentially the same as US4238298 except that impedance is measured at several fixed frequencies and the correlated impedance is then correlated to the corrosion rate.
- 1993—US5519330—introduces a pulsing instead of different frequencies. The pulses are of different amplitudes. A corresponding current is measured and correlated to the corrosion rate.
- 1998—US6132594—This is similar to many other methods that measure the voltages involved in corrosion except that it acknowledges that many localized corrosion can occur. For this reason, the corroded surface is segmented and many measurements are taken.
- 1999—US6275050 detects by injecting a signal into a junction and then detects 3rd Harmonics in particular. This is interesting, but not related to our problem as we are not concerned with measurement of junctions.
- 1999—US5905376 detects corrosion using MRI
- 2000—US5320395—is essentially the same as US4238298
- 2000—US6556001--is essentially the same as US4238298 except that it injects a noisy signal that changes over time. The resulting current is examined over time and mathematically manipulated to give the expected corrosion properties of the material.
- 2002—USH2127—detects by pulse heating a surface and then watching the phase of the response. This allows to see corrosion under a coating.
- 2003—US7057177—Finally, a new method. Here, infrared radiation is reflected off of a surface and the amount absorbed is determined. These two values are correlated to the amount of corrosion.
- 2003—US20030146749A1—Another new method that uses a magnetometer to measure the magnetic fields of the corroded magnetic materials.
- 2005—US20050274628A1—Essentially the same as US6132594
- 2005—US20050213430A1—A new method. Scan the surface of an article to the level of micrometers before corrosion and then after corrosion. Measure the difference at each point and statistically evaluate for the corrosion rate.
- 2006—US7388386—Uses a multitude of small plates of varying thickness. Each corrode through and break an electrical path.
- 2010—US20110067497A1—Uses ultrasound to measure the thickness of the sample to determine the amount of corrosion.

Step 3: Summarize the history.

Note that not all cases require the investigator to perform a patent search. We are conducting one in this case because we are interested in creating new and novel ways of measuring corrosion. Here is a summary of what was found:

- Pre 1956: Weight loss coupons—This is the oldest method. It consists of accurately weighing a sample (coupon) and then placing it into the corrosive environment for a specified length of time. After the time, the coupon is removed from the corrosive environment and cleaned of the corrosion. The coupon is then re-weighed and the rate of corrosion is determined from the difference in weights and the time in the corrosive environment. Weight loss coupons are the type of system that is being used in the acid container problem.

- 1956: Electrical resistance—Some of the first patents involved placing wires of the materials to be tested into the corrosive environments and then measuring the resistance of these wires over time as the cross section decreased due to corrosion.
- 1956: Linear polarization—This method involves reversing the galvanic voltage and measuring the resulting currents. This was developed around the same time as measuring electrical resistance and measuring the galvanic current.
- 1959: Galvanic current—involves measuring the actual currents involved in the corrosion process. These methods came about at about the same time as the electrical resistance methods.
- 1966: Irradiate sample with beta nuclear radiation and then measure back scatter and correlate with thickness of corrosion.
- 1977: Measure the rate of decay of the potential of the electric double layer. A charge is driven into the electric double layer and the potential is reduced by the corrosion.
- 1979: Apply alternating currents between test plates and measure the alternating current impedance. The corrosion rate is a function of the alternating current impedance.
- 1983: Measure the low frequency noise voltage between two electrodes immersed in the corrosive environment. The voltage is averaged and correlated to give the corrosion rate.
- 1999: Detect corrosion using MRI
- 2003: Infrared radiation is reflected off of a surface and the amount absorbed is determined. These two values are correlated to the amount of corrosion.
- 2003: Use a magnetometer to measure the magnetic fields of the corroded magnetic materials.
- 2005: Scan the surface of an article to the level of micrometers before corrosion and then after corrosion. Measure the difference at each point and statistically evaluate for the corrosion rate.
- 2006: Use a multitude of small plates of varying thickness. Each corrode through and break an electrical path.
- 2010: Uses ultrasound to measure the thickness of the sample to determine the amount of corrosion.

Each of these methods increased in precision and in the ability to operate over a wide range of operating conditions as evidenced by the patents. Most of these methods can be used to generate an instantaneous corrosion rate. In some cases, the level needs to be numerically differentiated to give an instantaneous corrosion rate.

L3-(Evolutionary History)—Identify Competitive Alternatives

This goes along with looking at the history. As a last resort, what have people used to perform this function if they don't have more expensive means of measuring it? The competitive alternative is what people currently use ***and*** what they would use if they didn't have what they are currently using. Remember that this is not necessarily what you would consider to be "the competition". For a pet watering bowl, the competitive alternative might be a large bucket. In the early stages, Southwest Airlines did not compete against other airlines; they were in competition with travel by car.

It is very tempting to go on personal experience to answer this question, but this is a trap. This is where many problem solvers and inventors go astray by assuming that they are like everyone else. There is wisdom in going to the battle to see how it is really being waged. There is no substitute for this. Don't be satisfied with talking to a few people.

Method

Step 1: Observe what the target market currently does to satisfy this function. If possible, go and watch before talking. By observing you get to the truth. What people do and what they say that they do are often two different things.

Step 2: Ask how they satisfy this function and what they would do if they didn't have what they currently use. This may give some valuable information into the history of the function. They will often offer what they did "way back when".

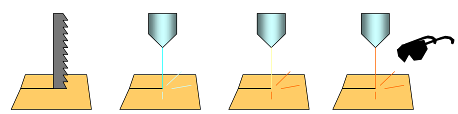
Step 3: Identify what "extreme users" currently do to satisfy this function and what they would do if they weren't using their current means. Extreme users often have a range of experience with uncommon ways to satisfy a function.

Step 4: Ask everyone that you interview where they go for the source of items and tools that they need to do these jobs. This will set you up for the next step.

L3-(Evolutionary History)—Evolution of Field Phenomena

This goes along with looking at the history because we are asking what we expect the phenomena to jump to if it were to change. We have to know the history to make this jump.

Examine the Table of Fields[19] shown below. Note that the top fields are the most abundant fields and the bottom fields are typically the least abundant. In general, systems tend to use the top fields first for muscle and then the lower fields for sensing and control.



Later, the lower fields may become more abundant. Since they are both abundant and controllable, it makes sense that systems evolve toward the bottom fields.

By examining the fields currently being used by your system, or similar systems, you can guess the fields that might be used next. Standard Solutions includes the replacement of poorly controlled fields with more easily controlled fields. [20] The Inventive Principles suggest the replacement of mechanical systems[21] with systems that use other than mechanical fields.

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19 Invention Machine software.

20 STANDARD 2-2-1. Efficiency of a SFM can be improved by replacing an uncontrolled (or poorly controlled) field with a well-controlled field, e.g. by replacing a gravitation field with mechanical field, mechanical field with an electric, etc. Notes: In certain situations, controllability of a field may be improved not only by replacing a given field with another one, but also by modifying the present field along the following line: Permanent field -> monotonically changing one -> pulsed one -> variable one -> variable in frequency and amplitude -> etc. Example: Instead of a metal blade for non-uniform metal cutting, a water jet can be used.

21 Inventive Principle #28—Replacement of Mechanical System: Replace a mechanical system with an optical, acoustical, thermal or olfactory system. Use an electric, magnetic or electromagnetic field to interact with an object. Replace fields that are Stationary with mobile. Fixed with changing in time. Random with structured. Use fields in conjunction with ferromagnetic particles. Genrich Altshuller, The Innovation Algorithm page 289.

Elastic Stress	Gravity	Friction	Adhesion			
Buoyant Force	Hydrostatic Pressure	Jet Pressure	Surface Tension			
Centrifugal Force	Inertial Force	Coriolis Force				
Oder & Taste	Diffusion	Osmosis	Chemical Fields			
Sound	Vibrations & Oscillations	Ultrasound	Waves			
Thermal Heating or Cooling	Thermal Shocks	Information				
Corona Discharge	Current	Eddie Currents	Particle Beams	Nuclear Forces		
Electrostatic Fields	Magnetic Fields	Electromagnetic Fields				
Radio Waves	Micro Waves	Infrared	Visible Light	Ultraviolet	X-Ray	Cosmic

Method

Step 1: What fields are currently being used to deliver this function?

Step 2: What are the next fields that will likely be used?

Example—Measuring Corrosion

Step 1: What fields are currently being used to deliver this function?

So far, we have seen all field phenomena represented from using weight (reduction of coupon mass) to looking at reflectance which uses light.

Step 2: What are the next fields that will likely be used?

The conclusion is to continue to evolve the use of electromagnetic waves such as light since there is nowhere more advanced to evolve.

L3-(Evolutionary History)—Disruptive Technologies

It is easy to get caught up in calling any great innovation a disruptive technology, but be careful how this term is used. Disruptive technologies[22] are those phenomena or scientific effects which have the potential of disrupting incumbent businesses, especially yours. These disruptive offerings are generally initiated in industries that are not your own, but adjacent industries.

Each market segment is focused on different competitive parameters in products that they use. Markets progress from performance (speed, power, etc) to reliability; then to convenience and finally to price. Those markets which are focused on performance and reliability never seem to be satisfied and continue to demand higher performance and reliability. They also tend to give the higher margins which make them more interesting markets. The lower end is already satisfied by the existing performance and reliability and is looking for convenience and price. It is usually possible to identify a disruptive technology because customers at the low end of the market are beginning to buy the competing products which offer convenience and lower price. Typically, the incumbent business is glad that this is happening because these customers are more difficult to satisfy when it comes to price. The margins are usually low for these products so they willingly shed these low-end customers. This seems innocent as these low end customers are not important to your business as you move up-market to gain higher and higher margins. Slowly, these offerings will gain in performance as they are fueled by the cash coming into these markets until you find that they are cutting into your mainline customers. Often, it is too late at this point because of the resources required to change over. History has shown that it is nearly impossible to copy a disruptive technology at this point. Vendors are often locked up while supplying the new supply chain. Consumers have loyalty to the early products. Giving away the lower end market also fuels the development of the disruptive technology until the performance and reliability are capable of encroaching on the main markets of the incumbent business. Eventually they take over the high end market. The disruption is complete and the incumbent is out of business.

Clayton Christensen coined the term “disruptive technologies” because migrating to the new technology is very disruptive to the incumbent business. For instance, they do not give the margins that you have come to expect. They do not intersect your supply chain. They do not satisfy the same levels of performance that your main customers have become accustomed to. They require new vendors. Often, a disruptive technology will require a whole new business model. This is the most disruptive of all. As management considers these technologies, they will reject them because they feel that they are doing this in the best interest of their company. Remember, they are held captive by their largest customers. Few resources are left over for other customers and disruptive technologies. He also gave the warning that businesses that feel that they are dealing with disruptors should move with extreme prudence or they will find themselves out of business in spite of otherwise excellent business practices. If nobody wants your product, you are out of business.

Many toppled businesses have seen these disruptors coming but were unable to respond adequately. The typical response is to try to force these disruptive technologies into existing markets with disastrous results. The new phenomenon is not capable of delivering the performance that the existing market has come to expect. The net effect usually proves to be too disruptive to be sustainable. Since adopting the disruptive technology is so disruptive, we will suggest an alternative approach that makes good economic sense and usually allows the business to compete with the existing business model. The approach is to move to a hybrid technology where the advantages of both technologies come together to create a new and unusual capability. This approach has weathered the test of time and the study of technical evolution shows that moving to hybrid technologies is a common means of transitioning to new physical phenomena. Using hybrid technologies allows the company to continue on a new enhanced performance curve and grow into the disruptive technology. At a minimum, the incumbent business will

22 The Innovator’s Dilemma by Clayton M. Christensen—Harper Business Essentials

continue to hold on to the mid and higher ends of the market. Since jumping to hybrid technologies is not a part of this step, we will discuss this later.

Method

Are there products which have a different technology that are lower in performance and reliability but which are offered at a lower price or are more convenient? Are these businesses viable, growing and are they eroding away the lower end of the markets that you normally serve? If the answer is "yes" then you are likely dealing with a disruptive technology.

Example—Corrosion Rate measurement

Are there products which have a different technology that are lower in performance and reliability but which are offered at a lower price or are more convenient? Are these businesses viable, growing and are they eroding away the lower end of the markets that you normally serve? If the answer is "yes" then you are likely dealing with a disruptive technology.

The two primary markets which require the measurement of corrosion rate appear to be corrosion testing services (which use standardized testing) and structural corrosion monitoring (which includes bridges, deep-sea oil rigs, boats and other structures which must spend a high percent of the time exposed to moisture).

The standardized testing industry has wide acceptance of weight-loss coupon testing to measure corrosion. The structural corrosion monitoring market widely accepts electrochemical methods which are very fast and have sufficient accuracy for corrosion monitoring.

The need for structural testing throughout the world suggests that improvements in electro-chemical methods could lead to rapid evolution of this technology. Due to the apparently low acceptance of electro-chemical testing for standard tests, everything is pointing to electrochemical monitoring as a disruptive technology for coupon testing. Also, ASTM has held symposia and presented peer-reviewed papers to promote its use for standardized testing. We might well see this technology rapidly taking over in the testing services markets.

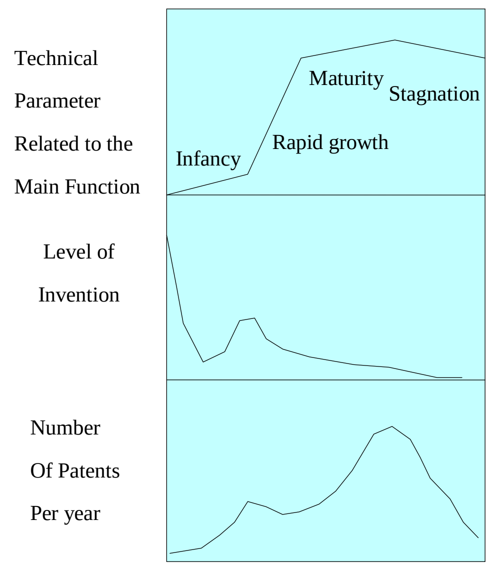
L3-(Evolutionary History)—Determine the System Maturity from Patents

The maturity of systems can be determined by several means. One means is by the study of patents[23]. This involves understanding the increase in performance of the main technical parameter related to main technical function, the level of invention and the number of patents over time. The method shown is very time consuming and should be applied if other methods prove ineffective in showing the importance of switching to a new physical phenomenon.

Method for Examining System Maturity

Step 1: Identify the technical parameter related to the main function. Quantify how this has improved over time.

Step 2: Identify how the level of invention has changed over time. The level of invention is typically high when changing to a new physical phenomenon. It peaks again during the period of rapid growth as resources are made available from sales. Later, it levels off as system resources are exhausted.



The level of invention is as follows:

——1. No resolution of contradiction

——2. Resolves contradiction with small change

——3. Resolves contradictions with a major change. It uses technology from the same field.

——4. Complete change in physical phenomenon. This is usually a technology from another field.

——5. New Physical Phenomenon. Has ability to change the super-system to which it belongs.

Step 3: Quantify the number of patents per year.

23 Creativity as an Exact Science-The Theory of the Solution of Inventive Problems by G.S. Altshuller. Gordon and Breach. Page 207

L3-(Switch Phenomena?)—Is it Time for a Switch?

The main reason that we would like to know the system maturity is because it is particularly important to determine whether there is a need to change to a new physical phenomenon to perform the main modification of the system product. A new physical phenomenon brings fresh resources which allow continued evolution of the function or the job that is being performed. Unfortunately, it also involves unknown risks and unfamiliarity of the side effects of the new phenomenon. An additional shortcoming of going to a new physical phenomenon is that the customer has come to accept certain levels of performance which will almost certainly not be achieved unless the transition is brought about through the use of hybrid phenomena which will be described later.

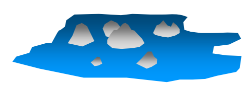
Required Conditions for a New Phenomenon

If several of these conditions are present then consider a new physical phenomenon to deliver the main modification.

Condition 1: There are a large variety of these types of systems that have become specialized into niche markets.

Condition 2: The super-system has reached the point of diminishing return. Are the main technical parameters improving very slowly? If they are not, then the economic competition for the existing phenomenon or technology will likely be too intense to even create an advantage.

Condition 3: Automatic feedback[24] *is used to perform the main super-system function. By the point that systems are using massive feedback, we can usually assume that the system is running out of resources. This is because the use of feedback is costly, indicating that costly improvements are required to bring minor changes to performance.*



Condition 4: Multiple conflicts must be resolved for even minor improvements. (Many rocks appear when we begin to drain the pond) It is typical that products and services will be filled with compromise "solutions". Between major improvements in the product, there is a tendency to ignore risks and to live with compromises. As time goes on and the product becomes specialized, these compromises mount up until changes in the operating environment expose multiple compromises.

Example—Measuring Corrosion Rate

In the case of measuring the corrosion rate, we now know some things about the history of measuring corrosion or corrosion rate. If we focus on the incumbent technology of coupon weight tests for standard corrosion testing then question that we are trying to answer is related to moving from coupon testing to other form or corrosion testing. The main competition comes from structural corrosion testing which uses a different technology. As far as standard testing is concerned, electrochemical corrosion testing can be considered a disruptive technology that may soon be disrupting the slower methods of coupon testing. While there are other possibilities in the patent literature, electrochemical corrosion testing is the most advanced.

24 17 Secrets of an Inventive Mind: How to Conceive World Class Products Rapidly Using TRIZ and other Leading Edge Creative Tools by James Kowalick

If several of these conditions are present then consider a new physical phenomenon to deliver the main modification.

Condition 1: There are a large variety of these types of systems that have become specialized into niche markets.

Standardized corrosion testing using coupons has been around for a long time. The corrosion testing services appear to be quite mature and specialized whereas the structural testing appears to continue to grow into diverse markets.

Condition 2: The super-system has reached the point of diminishing return. Are the main technical parameters improving very slowly? If they are not, then the economic competition for the existing phenomenon or technology will likely be too intense to even create an advantage.

When it comes to corrosion testing, the speed of coupon testing appears to be improving very slowly. This opens up the possibility to introduce electrochemical corrosion testing into the standard corrosion testing environment.

Condition 3: Automatic feedback[25] is used to perform the main super-system function. By the point that systems are using massive feedback, we can usually assume that the system is running out of resources. This is because the use of feedback is costly, indicating that costly improvements are required to bring minor changes to performance.

The author did not come across substantial evidence that coupon testing has implemented feedback.

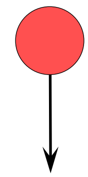
Condition 4: Multiple conflicts must be resolved for even minor improvements. (Many rocks appear when we begin to drain the pond) It is typical that products and services will be filled with compromise "solutions". Between major improvements in the product, there is a tendency to ignore risks and to live with compromises. As time goes on and the product becomes specialized, these compromises mount up until changes in the operating environment expose multiple compromises.

Several conflicts arise to increase the speed of coupon testing. Measurement of the change of weight is the primary problem. The change in weight as a percentage of the whole weight of the coupon is a problem. As the percentage becomes lower and lower, the noise in the experiment increases. Another problem is that the means of dislodging the small amounts of corrosion must not remove the base material that is being tested. Another consideration is that there is a difficulty in removing all of the corrosion when it lodges itself into surface pits. This becomes more difficult when the amount of corrosion is low. Multiple conflicts, alone, do not condemn a physical phenomenon.

Summary: It is probably time to switch to a new phenomenon and the most likely is electrochemical methods since they are in a stage of rapid increase for monitoring corrosion.

25 17 Secrets of an Inventive Mind: How to Conceive World Class Products Rapidly Using TRIZ and other Leading Edge Creative Tools by James Kowalick

L3-(Potential Phenomena)—Secondary Phenomena



We start with this method because it lays the ground work for a lot of the approaches that follow. For this method, we are looking for other characteristics of the object that is being measured that change over time due to a change in the main parameter that we are measuring. Rather than directly measuring the parameter, a second parameter can be measured which is influenced by the one that you would like to measure.[26] Object parameters always influence each other. The temperature of an object affects its dimensions. The weight of an object affects its buoyancy. In reality, almost all parameters are measured by measuring a secondary parameter and then inferring the required measurement. It may be necessary to consider various physical phenomena to identify a good secondary phenomenon.[27] In order to get a good list of parameters that could change, we consult the book "Mobilizing Idle Function Resources" to identify as many physical phenomena that change as possible.

Method

Step1: What exact parameter requires detection?

Step 2: List secondary parameters that change when the main parameter changes. Consider referring to the book Identifying and Mobilizing Function Resources to identify the secondary parameters.

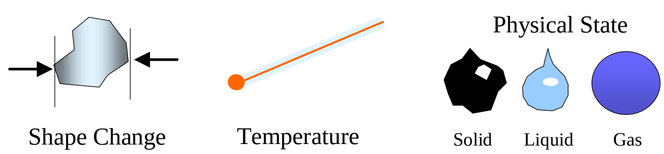
Step 3: Detect these secondary parameters instead.

Example—Measurement of Pressure

Step1: What exact parameter requires detection?

Pressure

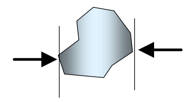
Step 2: List secondary parameters that change when the main parameter changes. Consider referring to the book Identifying and Mobilizing Function Resources to identify the secondary parameters.



26 STANDARD 4-2-1. If a non-SFM is not easy to detect or measure, the problem is solved by synthesizing a simple or dual SFM with a field at the output. Instead of direct measurement or detection of a parameter, another parameter identified with the field is measured or detected. The field to be introduced should have a parameter that we can easily detect or measure, and which can indicate the state of the parameter we need to detect or measure. Example: To detect a moment when a liquid starts to boil, an electrical current is passed through the liquid. During boiling, air bubbles (S2) are formed - they dramatically reduce electrical conductance of the liquid.

27 STANDARD 4-3-1. Efficiency of a measuring SFM can be improved by the use of physical effects. Example: Temperature of liquid media can be measured by measuring a change of a coefficient of refraction, which depends on the value of the temperature.

Step 3: Detect these secondary parameters instead.



Example—Measuring Corrosion

Step1: What exact parameter requires detection?

Rate of corrosion

Step 2: List secondary parameters that change when the main parameter changes. Consider referring to the book Identifying and Mobilizing Function Resources to identify the secondary parameters.

Below is the list of the properties of the corroded metal that would change with corrosion. Note that while the list is quite long, properties which implied the need to contact or disturb the surface were not included such as surface hardness, ductility or toughness. The more ideal scientific effects do not require contact. Note that many of these methods were not considered in the foregoing patent search on measuring corrosion. (This means that there is an opportunity for someone to create new devices for detecting corrosion).

No Fields Implied

Structural shape of the surface

Fractal dimension of surface

Number of active sites

Interaction site surface area

Change in coupon weight

Number of voids

Porosity

Activity of sites

Coupon thickness

Height above original surface

Coupon Volume

Surface density

Surface Molecular Weight

Thermal Implied

Surface Thermal Conductivity

Surface Thermal Capacity

Magnetic Implied

Surface Magnetic Permeability

Surface Magnetic Hysteresis

Surface Curie Point

Electrical Implied

Surface DC impedance

Surface AC impedance

Surface electrical continuity

Surface Ionization Potential

Surface Electric Permittivity

Optical Implied

Optical reflectivity

Optical emissivity

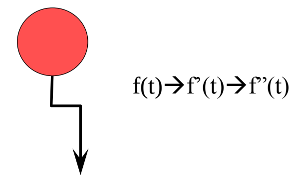
Optical absorption

Optical scattering

Step 3: Detect these secondary parameters instead.

L3-(Potential Phenomena)—Derivative Detection

One of the most powerful ways to measure a parameter is to measure the rate of change and then integrate.[28] (Measuring and then differentiating is also possible, but it is quite noisy). With modern computing, integration schemes are easily accomplished. It is also possible to integrate with analogue circuits. This method can also be used to measure any of the secondary phenomena that we have identified.



Method

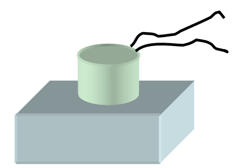
Step 1: Measure higher order derivatives.

Step 2: Integrate as many times as necessary to determine the desired parameter.

Example—Measurement of Relative Position of an Object

Step 1: Measure higher order derivatives.

Place an accelerometer on the object and measure acceleration.



Step 2: Integrate as many times as necessary to determine the desired parameter.

Integrate twice to determine the relative position of the object.

$$\iint \ddot{X}\ dt =$$

28 STANDARD 4-5-2. Measuring systems evolve towards measuring the derivatives of the function under control. The transition is performed along the following line: measurement of a function –-> measurement of the first derivative of the function –-> measurement of the second derivative of the function. Example: Change of stress in the rock are defined by the speed of changing the electrical resistance of the rock.

L3-(Potential Phenomena)—Already Poorly Performed by Native Fields

The functions that we are trying to deliver may already be happening due weak or difficult to observe fields that are already present. Often, these functions are being performed in such a weak manner that we don't notice them. We also might not recognize them because they are deemed to be harmful. With a little help, we can boost these functions until they become useful[29].

Method

Step 1: Is the function already delivered by a super-system observer, even poorly or delivering a harmful function?

Step 2: What physical phenomenon is employed to poorly deliver this function?

In following steps we can ask what modifications to the fields or the observer allow the function to be boosted. These modifications may require the small addition of substances or structures which react strongly to the native fields.

Example—Corrosion Measurement

We have been considering corrosion by the use of capacitive load. Is it possible that native fields are already at play?

Step 1: Is the function already delivered by a super-system observer, even poorly or delivering a harmful function?

A super-system observer would be any object in the super-system that would or might change its capacitance due to a change in corrosion of the cubes being measured. It is possible that we might find that objects near to the corroded cubes might have a changed capacitance.

One possibility is to monitor the liquid surrounding the cubes for a change in capacitance, especially if the liquid is allowed to deplete its charges which cause the corrosion. The function is to change the dynamic impedance as a function of the corrosion.

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29 STANDARD 5-2-1. If a field has to be introduced in a SFM, one should use first of all the present fields for whom the media are those substances that form the system or its part. Note: The use of substances and fields which already present in the system improves the system's ideality: number of functions performed by the system increases without increasing the number of used components.

STANDARD 5-2-2. If a field has to be introduced in a SFM and it is not possible to use the fields which already present in the system, one should use the fields of the external environment. Note: The use of external environment fields (gravitation, thermal field, pressure...) improves the system's ideality: the number of functions performed by the system increases without increasing the number of used components.

STANDARD 5-2-3. If a field has to be introduced in a SFM but it is impossible to use the fields which already present in the system or in the external environment, one should use the fields for whom the substances present in the system or external environment can act as media or sources. Notes: In particular, if there are ferromagnetic substances in a system and they are used for mechanical purposes, it is possible to use their magnetic properties in order to obtain additional effects: improve interactions between components, obtain information on the state of the system, etc.

Step 2: What physical phenomenon is employed to poorly deliver this function?

The physical phenomenon is the depletion of charges in the corroding fluid by the action of corrosion of the cubes.

In following steps we can ask what modifications to the fields or the observer allow the function to be boosted. These modifications may require the small addition of substances or structures which react strongly to the native fields.

The modification of the fields would occur as we changed the initial volume of corroding fluid thus changing the susceptibility to oscillating fields.

L3-(Potential Phenomena)—Analogous Measurement

The preceding use of secondary phenomena has set us up for this approach. The idea of analogous measurement is to find situations in other industries where either the direct measurement of the parameter or the characteristics which we have just discovered using secondary phenomena are measured. Then we look at the physical phenomena or scientific effect used there. An analogous phenomenon[30] produces the required transformation. Stating the modification in a shortened generic format allows us to open our minds to other phenomena that can perform the function. This can be transferred to our situation with satisfying results. If we look in industries that perform a function on a massive scale[31], we can often find the best evolutionary path to date. This method can also be used to measure any of the secondary phenomena that we have identified.

Method

Step 1: Start with the required change of properties of the observer due to a change of properties of the object being measured.

Step 2: State this in the short generic format.

Step 3: What other objects require the same measurement?

Step 4: Transfer this feature to the new situation. Consider combining this with the existing subject or transferring the minimum amount of the subject.

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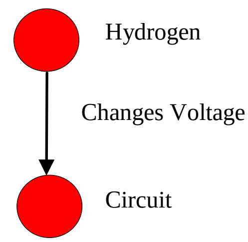
30 No specific reference is given for this tool. The author has heard rumor that there might be a table of analogous phenomena in existence somewhere in the world. It is not necessary to have a table to use this method, but would be helpful if such a table existed.

31 The Innovation Algorithm by G.S. Altshuller, Technical Innovation center. First Edition 1999 page 174. Used as part of ARIZ 71. "Compare the by-pass problem with a tendency (a direction of evolution) in a leading industry."

Example—Voltage Change Due to Temperature Change of Hydrogen Gas

Step 1: Start with the required change of properties of the observer due to a change of properties of the object being measured.



The voltage of the observer object must change due to a temperature change of the gas.

Step 2: State this in the short generic format.

Temperature changes voltage. (T→V)

Step 3: What other objects require the same measurement?

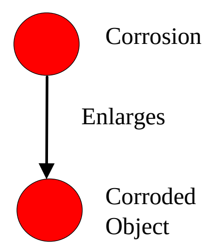
Oven temperature sensing requires a change of voltage due to a change of gas temperature.

Combustion sensors in automobiles are an example where lots of sensors are built. The evolutionary trends that we see here may be preferable to other industries.

Step 4: Transfer this feature to the new situation. Consider combining this with the existing subject or transferring the minimum amount of the subject.

Example—Corrosion Measurement

Step 1: Start with the required change of properties of the observer due to a change of properties of the object being measured.



The height of the coupon must change due to the change of height of the corrosion.

Step 2: State this in the short generic format.

Corrosion enlarges object being corroded

Step 3: What other objects require the same measurement?

We are looking for other situations where something is added to a surface and then needs to be measured. Here are some examples: plating depositions, paint, and dyes are used to coat surfaces. Next, we ask how these are measured in their various industries. For the sake of illustration, let's look into how depositions are measured. This is a good one because depositions can be very thin and we want to measure something that is happening very rapidly which means that by the time the corrosion is measured, it hasn't had much time to grow very thick. An internet search turns up a possibility: that deposition can be measured by using a reflectance probe and a light source. The reflectance probe is coupled with a spectrometer and the thickness is detected by detecting the fringe pattern from the light reflection.

Step 4: Transfer this feature to the new situation. Consider combining this with the existing subject or transferring the minimum amount of the subject.

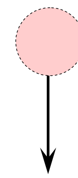
There appears to be a number of manufacturers of this type of equipment. Note that corrosion usually eats into the surface and then has a higher volume than the virgin material. This means that the total thickness will be higher than the measured thickness which will likely require a mathematical correlation between the measured thickness and the actual thickness. We could do this for every characteristic above, but these pages don't have the space for that. Suffice it to say that we can find many ways to measure corrosion using this method.

L3-(Potential Phenomena)—Measure a Copy or Facsimile

When it is difficult to measure an attribute, that you would like to measure it may be possible to measure a copy[32] [33]of the genuine article. Following is a list of possible copies. This method can also be used to measure any of the secondary phenomena that we have identified.

- Photographs
- Movies
- Paint Coverings
- Molds
- Time lapse photos
- Impressions

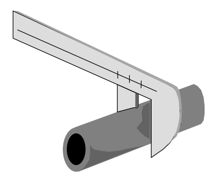
- Silhouettes
- Castings
- Resists
- Projections
- Computer Model



Method

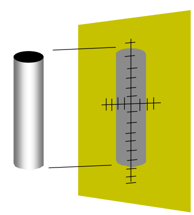
Measure a facsimile of the article. Consult the list of possibilities in the tan colored boxes.

Example—Measurement of the Dimensions of an Elastic Article



Traditional measuring instruments such as calipers tend to deform the article during measurement.

Measure a facsimile of the article. Consult the list of possibilities in the tan colored boxes.



Measure the Silhouette

Example—Corrosion Measurement

Find new ways to measure the rate of corrosion in metal samples which take much less time than common methods.

Measure a facsimile of the article. Consult the list of possibilities in the tan colored boxes.

Take a picture of the corroded surface using a variety of wavelengths. These pictures can then be digitally enhanced and evaluated. Processing time may be longer than some of the other methods, but, at least, the specimen does not need to be in the acid for very long.

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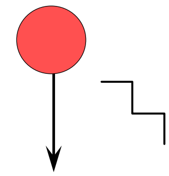
32 Inventive Principle #26—Copying: A simplified and inexpensive copy should be used in place of a fragile original or an object that is inconvenient to operate. If a visible optical copy is used, replace it with an infrared or ultraviolet copies. Replace an object (or system of objects) with their optical image. The image can then be reduced or enlarged. Genrich Altshuller, The Innovation Algorithm page 288.

33 STANDARD 4-1-2. If a problem involves detection or measurement, and it is impossible to change the problem to eliminate the need for detection or measurement, it is proposed to detect/measure properties of a copy of the object (e.g. picture). Example: It might be dangerous to measure the length of a snake. It is safe to measure its length on a photographic image of the snake, and then recalculate the obtained result.

L3-(Potential Phenomena)—Discrete Detection

This thought tool is very similar to the concept of pre-measurement. In this step, we compare the parameter of an object to the same parameter of another object that comes only at discrete levels. [34] This method can also be used to measure any of the secondary phenomena that we have identified.

Method



Step 1: How accurate does the measurement need to be?

Step 2: Break the levels of measurement, or the measurement of a secondary parameter into discrete levels. Create these levels in a second device. Examples are: Discrete volumes, Filters, Musical notes, Go-No-Go gages, Measuring spoons, Set of Weights.

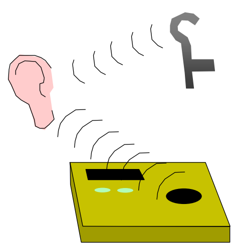
Step 3: Compare the object being measured or detected to the discrete values.

By ear, compare the musical note to the resonance. The musical note has a known frequency.

Example—Measuring the Resonant Frequency of Objects

Step 1: How accurate does the measurement need to be?

It needs to be within 50 Hz.



Step 2: Break the levels of measurement, or the measurement of a secondary parameter into discrete levels. Create these levels in a second device. Examples are: Discrete volumes, Filters, Musical notes, Go-No-Go gages, Measuring spoons, Set of Weights.

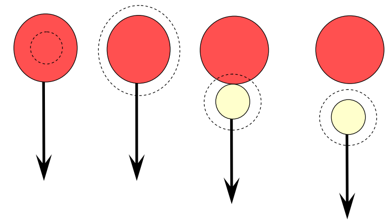
For the detection of the frequency, we will use a digital musical instrument which plays discrete notes

Step 3: Compare the object being measured or detected to the discrete values.

By ear, compare the musical note to the resonance. The musical note has a known frequency.

34 STANDARD 4-1-3. If a problem involves detection or measurement, and the problem cannot be changed to eliminate the need for measurement, and it is impossible to use copies or pictures, it is proposed to transform this problem into a problem of successive detection of changes. Notes: Any measurement is conducted with a certain degree of accuracy. Therefore, even if the problem deals with continuous measurement, one can always single out a simple act of measurement that involves two successive detections. This makes the problem much simpler. Example: To measure a temperature, it is possible to use a material that changes its color depending on the current value of the temperature. Alternatively, several materials can be used to indicate different temperatures.

L3-(Potential Phenomena)—Field Markers



This method can be used to measure the main parameter or any of the secondary phenomena that we have identified. It is hard to measure something that you can't detect in the first place. Try measuring the length of something in a dark room. One must first be able to detect substances or fields before they can be quantitatively measured. Once a substance or field can be detected then we can measure a variety of parameters such as existence, location, path, velocity, degree of segmentation, voids, volume, surface structure, state of matter, bulk properties, gradients of components, existence of fields, filed direction, field gradients, field location, speed, and frequency. However, note that each of these parameters can be measured because either a substance or a field is "detectable". One way to make a substance or field detectable is using markers.

Most of the time that we are measuring a parameter, what we are actually measuring is fields associated with the parameter. When it is difficult to detect or measure a desired parameter, often it is because the materials involved do not have strong fields that can be measured. Markers are a special type of additive that adds fields to the system making them easier to detect. Often, the detection comes directly by sight, feel, smell or taste. We would like to avoid adding substance markers to a system, if possible. One of the ways to avoid adding material markers to the subject is to add a temporary or permanent field marker[35] instead. By introducing a field into the system, it is possible to then detect or measure the effect of the changing parameter on the field rather than the substance, though it may not permanently reside in the system.

Internal Field Markers

Internal field markets inhabit the substance of the measured object. Certain fields have the ability to distribute themselves through the bulk of the material. However, the fields or their effects are not constrained to the measured subject. These fields can "leak" out and be detected. An example of this is a thermal field. The subject being measured can become hot or cold. This effect extends into the environment as radiation or heating of the environment which can be detected. Other fields create different types of fields outside of the measured object. For instance, a current field can inhabit an object and external magnetic fields are generated that can be measured.

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35 This comes from several standards. The first three involve using substance additives as markers. The last states that if a physical substance is required and cannot be used, then a field can be used instead. The result is the use of field markers rather than substance markers. STANDARD 4-2-2. If a system (or its part) does not provide detection or measurement, the problem is solved by transition to an internal or external complex measuring SFM, introducing easily detectable additives. Example: To detect leakage in a refrigerator, a cooling agent is mixed with a luminescent powder.

STANDARD 4-2-3. If a system is difficult to detect or to measure at a given moment of time, and it is not allowed or not possible to introduce additives into the object, then additives that create an easily detectable and measurable field should be introduced in the external environment. Changing the state of the environment will indicate the state of the object. Example: To detect wearing of a rotating metal disc contacting with another disk, it is proposed to introduce luminescent powder into the oil lubricant, which already exists in the system. Metal particles collecting in the oil will reduce luminosity of the oil.

STANDARD 4-2-4. If it is impossible to introduce easily detectable additives in the external environment, these can be obtained in the environment itself, for instance, by decomposing the environment or by changing the aggregate state of the environment. Notes: In particular, gas or vapor bubbles produced by electrolysis, cavitation or by any other method may often be used as additives obtained by decomposing the external environment. Example: The speed of a water flow in a pipe might be measured by amount of air bubbles resulting from cavitation.

STANDARD 5-1-1-2. If it is necessary to introduce a substance in the system, and it is not allowed, a field can be introduced instead of the substance.

Surface Field Markers

Sometimes, a field will disrupt a substance enough that it should not inhabit the subject. Also, some fields are principally associated with surface phenomena and cannot inhabit the subject. Here we consider fields that reside on the subject, but are not associated with any other substances but the subject. Again, these fields "leak out" or create other fields that can be detected.

Attached Field Markers

If no fields can inhabit the subject or its surface, then consider adding a field to objects already attached to the measured object.

Detached Field Markers

Some of the field-substance couples in the attached field materials will disrupt the subject or detached object. If this is the case, then there may be secondary effects that the subject causes on the environment which can be measured by recognizing an existing field or introducing a field into the immediate environment and then detecting the effect of the measured object on that field.

Method

Step 1 Internal Fields: Search this list of fields for one that already inhabits or can inhabit the bulk of the subject. Once the subject has this added field, how does it manifest itself outside of the measured object? We can allow for some of these fields to exist momentarily or they may require a constant source.

- Internal Stress (May externally manifest a change in shape, curvature, movement with the changing parameter.)
- Inertial Force (May externally manifest a change in path, curvature or movement with the changing parameter)
- Hydrostatic Pressure (May externally manifest a change in shape, curvature or movement with the changing parameter if the pressure is contained. If not contained, it may manifest a change in density or a change in bubble volumes or gases coming out of solution.)
- Vibration / Sound / Ultrasound (May externally manifest harmonics, movement, ejected particles, radiated vibrations)
- Current (May manifest a change in the external magnetic or electromagnetic field or heating with the changing measured parameter.)
- Thermal Field (May manifest changing external radiation, conduction or convection and electromagnetic fields such as infrared or light if hot enough)
- Magnetic Field (May externally manifest a changing magnetic field)
- Electrostatic fields (trapped charge such as holes may be manifest as changing electrostatic fields or induced field gradients in external objects)
- Electromagnetic Fields (May be manifest as changing electromagnetic fields radiated from the object.

Step 2 Surface Fields: Search this list of fields for ones that is already attached or can be permanently or temporarily attached to the subject. Once the subject surface has this added field, how does it manifest itself away from the surface? We can allow for some of these fields to exist momentarily or they may require a constant source.

- Surface Stress (compressive or tensile—may externally manifest as a change in shape, curvature, movement with the changing parameter if the surface to volume ratio is high)
- Surface Tension (May externally manifest itself as a change in shape, curvature or movement of external objects)

- Skin Current traveling across the surface (May externally manifest as changing radiated electromagnetic fields)
- Electrostatic fields (charges confined to surface of conductors—may be manifest as changing external electrostatic fields or induced field gradients in external objects)
- Reflected light from surface (May be externally manifest as a changing radiated electromagnetic field)
- Radiation from surface (May be externally manifest as a changing radiated electromagnetic field)

Step 3 Fields in or on attached objects: Attach objects or identify already attached objects and consider introducing the same fields from step 1 and 2 above.

Step 4: Fields in the environment: Search the list of fields below for fields that exist or can be added permanently or temporarily into the environment. Can changes in the parameter that you would like to measure change these fields in any way?

- Elastic Stress (Is the environment solid? Can the stresses change with a change in the measured parameter? May be externally manifested in the movement or deformation of the environment?)
- Gravity (Does weight or orientation of the environment change due to a change in the parameter?)
- Friction (Does the friction between objects in the environment change due to change in measured parameter? May be manifest by slippage between objects)
- Adhesion (Does the adhesion of objects in the environment change due to changes in the measured parameter? May be manifest by segmentation of objects which are normally adhered)
- Buoyant Force (Does the buoyancy of objects in the environment change due to changes in the measured parameter? May be manifest by movement of bodies or fluids)
- Hydrostatic Pressure (Most objects exist in fluids. Does the changing parameter affect the hydrostatic pressure of the fluid? May be manifest by changes on curvature, shape or size of contained objects in the environment. May be manifest by bubble size or gas coming out of solution.)
- Jet Pressure (Is the fluid environment moving or can it be made to move? Does the changing parameter change the pressure of the fluid as it moves around objects? May be manifest by changes on curvature, shape or size of contained objects in the environment. May be manifest by bubble size or gas coming out of solution.)
- Surface Tension (Does a change in the parameter change the surface tension which exists at the interface between states of matter? May externally manifest itself as a change in shape, curvature or movement of fluid interfaces.)
- Centrifugal Force (spin the environment so that there is outward motion. Do the centrifugal forces in the environment change with a change in the measured parameter? May be manifest by changes or gradients in hydrostatic or jet pressures, see above.)
- Inertial Force (put the environment into motion so that it has momentum. Does the momentum change when the parameter being measured changes? May be externally manifested by velocity changes or movement of impacted objects.)
- Coriolis Force (put the environment into motion. Do the Coriolis forces change when the parameter being measured changes? May be manifest by changing motion or alignments of objects.)
- Odor and Taste (Is there an odor or taste change due to a change of the parameter?)
- Diffusion (Are there normal diffusion processes associated with the measured object or objects in the environment? Is this diffusion affected by the changing parameter? May be manifest by smell or taste; chemical gradients.)
- Osmosis (Are there objects in the environment that experience osmosis? Do the changing parameters affect the osmosis in these objects? May be externally manifest by changes in ion concentration on either side of osmotic membranes.)

- Chemical Fields (Are there compounds in the environment that might be affected by changes in the measured parameter? May be externally manifest by changes in chemical gradients, optical properties of compounds affected; temperatures)
- Sound / Vibration & Oscillations / Ultrasound / Waves (Almost always, there is matter in various states in the environment. Do changes in the measured parameter change conductance, intensity, gradients, harmonics, and resonance of objects in the environment?)
- Thermal fields / Thermal shocks (Does a change in the parameters affect the temperature or temperature gradient of the external medium? May manifest external radiation, conduction or convection and electromagnetic fields such as infrared or light if hot enough)
- Information (Does a change in the parameter affect information or the availability of information in the environment? May manifest external loss or changes in data.)
- Corona discharge (Does a change in the parameter change surface voltages in the environment? Does it affect availability of ionizing radiation? May manifest itself externally as the creation of corona discharge or a change in intensity)
- Current / Eddie Currents (Is the environment conductive? Is there already or could electrical current be introduced into the environment? Does a change of the parameter affect the resistivity, capacitance or inductance of the environment?)
- Particle beams (Can charged particle beams be introduced into the environment? Does a change of the measured parameter change the charge density of objects in the system, thus changing the path of the beam?)
- Nuclear forces (Do the atomic elements in the environment change when the measured parameters change? Are the elements that change detectable with Nuclear Magnetic Resonance techniques?)
- Electrostatic fields (charges are usually confined to the surface of conductors in the environment. Does a change of the measured parameter redistribute charges in the measured object?—may be manifest as external electrostatic fields or induced field gradients in external objects)
- Magnetic fields (Does a change in measured parameter affect current flow or magnetic fields that emanate into the environment? May manifest externally as a change in magnetic intensity or a change in charge movement in the environment.)
- Electromagnetic fields /Radio waves / Microwaves / Infrared / Visible light / Ultraviolet / X-ray / Cosmic rays. (Can a change in the measured parameter affect the absorption, conductance, reflectance, polarization or emission of electromagnetic waves from objects in the environment? May manifest as a change in intensity, direction or polarization)

Example—Determining the Direction of Flow in a Pipe

How can the direction of flow of a liquid be detected in a pipe?

Step 1 Internal Fields: Search this list of fields for one that already inhabits or can inhabit the bulk of the subject. Once the subject has this added field, how does it manifest itself outside of the measured object? We can allow for some of these fields to exist momentarily or they may require a constant source.

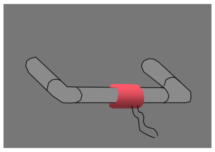
Sound and vibrations can inhabit the bulk of the water. Solution: Sound is introduced and the time to move a set distance is measured in both directions. A sound introduced in the pipe will have two paths. One is in the pipe and another is in the liquid. The sound travels faster in the pipe than in the liquid and since the pipe is stationary, the time to travel to the pickups will be the same if the distance is the same. This path can be used as the reference sound. The time to travel through the moving fluid is longer than in the pipe. The sound traveling with the liquid will move faster than against the flow of the liquid. An external microphone can detect the sound traveling through the liquid as a secondary signal on both sides of the pipe, thus giving a measurement of the velocity of the liquid. The difference between the sound traveling through the liquid and the reference sounds can be used to make the calculation of speed.

Step 2 Surface Fields: Search this list of fields for ones that is already attached or can be permanently or temporarily attached to the subject. Once the subject surface has this added field, how does it manifest itself away from the surface? We can allow for some of these fields to exist momentarily or they may require a constant source.

Since the pipe surrounds the water, it is difficult to attach a field to the surface of the water. No field or physical phenomena is found.

Step 3 Fields in or on attached objects: Attach objects or identify already attached objects and consider introducing the same fields from step 1 and 2 above.

Thermal fields can inhabit the pipe which is attached to the liquid. Solution: A heat cuff is attached to the pipe. The water absorbs the heat into its bulk. The pipe becomes hotter downstream of the cuff. Detect the heat by touch.

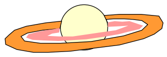


Step 4: Fields in the environment: Search the list of fields below for fields that exist or can be added permanently or temporarily into the environment. Can changes in the parameter that you would like to measure change these fields in any way?

In this case, the pipe is both the attached object and the environment of the liquid. The solution of step 3 fulfils step 4.

Example—Measuring the Rotational Speed of the Rings of Saturn.

How can the rotation speed of the rings of Saturn be measured?



Step 1 Internal Fields: Search this list of fields for one that already inhabits or can inhabit the bulk of the subject. Once the subject has this added field, how does it manifest itself outside of the measured object? We can allow for some of these fields to exist momentarily or they may require a constant source.

Electromagnetic fields may be able to inhabit some of the components of the rings if they are transparent or translucent. The red-shift might be detected from radiation which leaves the bulk of these bodies.

Inertial forces inhabit the constituents of the rings. If it is possible to know the gravitational force as a function of distance then the velocity necessary to hold the rings in their positions can be calculated.

Step 2 Surface Fields: Search this list of fields for ones that is already attached or can be permanently or temporarily attached to the subject. Once the subject surface has this added field, how does it manifest itself away from the surface? We can allow for some of these fields to exist momentarily or they may require a constant source.

Reflected or emitted Light can be attached. The Doppler shift of reflected light allows detection of ring velocity. (Opposite sides of ring have different shift).

Step 3 Fields in or on attached objects: Attach objects or identify already attached objects and consider introducing the same fields from step 1 and 2 above.

No solution is given.

Step 4: Fields in the environment: Search the list of fields below for fields that exist or can be added permanently or temporarily into the environment. Can changes in the parameter that you would like to measure change these fields in any way?

No solution is given

Example—Tracking Wild Animals

How can the position of a wild animal be tracked?

Step 1 Internal Fields: Search this list of fields for one that already inhabits or can inhabit the bulk of the subject. Once the subject has this added field, how does it manifest itself outside of the measured object? We can allow for some of these fields to exist momentarily or they may require a constant source.

Sounds inhabit the animal. If a characteristic sound is given emitted then the animal may be tracked using this sound.

Step 2 Surface Fields: Search this list of fields for ones that is already attached or can be permanently or temporarily attached to the subject. Once the subject surface has this added field, how does it manifest itself away from the surface? We can allow for some of these fields to exist momentarily or they may require a constant source.

No solution is given.

Step 3 Fields in or on attached objects: Attach objects or identify already attached objects and consider introducing the same fields from step 1 and 2 above.

A small antenna can be inhabited by an alternating electric current which gives off an electromagnetic field. An emitting antenna is attached to the animal. The antenna's field is detected by another antenna and amplifying circuit. Triangulation tells where the animal is.

Step 4: Fields in the environment: Search the list of fields below for fields that exist or can be added permanently or temporarily into the environment. Can changes in the parameter that you would like to measure change these fields in any way?

Old time tracking is noticing the patterns of changing stress in the environment caused by animals moving about.

Another thing that changes due to the presence of animals is odor. Again, we can use the sensitive smell of dogs to track the animals.

Example—Detecting Planets in Other Solar Systems

How can planets in other solar systems be detected?

Step 1 Internal Fields: Search this list of fields for one that already inhabits or can inhabit the bulk of the subject. Once the subject has this added field, how does it manifest itself outside of the measured object? We can allow for some of these fields to exist momentarily or they may require a constant source.

Stars and planets are inhabited by inertial forces which are affected by attraction by gravity. Small changes in path can be used to detect planets.

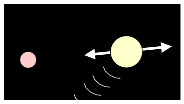
Magnetic fields inhabit planets and stars. If the planet is close enough to the star then the magnetic field of the star may be altered. Magnetic fields disturb the movement of charged particles which may be detected.

Step 2 Surface Fields: Search this list of fields for ones that is already attached or can be permanently or temporarily attached to the subject. Once the subject surface has this added field, how does it manifest itself away from the surface? We can allow for some of these fields to exist momentarily or they may require a constant source.

No Solution is given.

Step 3 Fields in or on attached objects: Attach objects or identify already attached objects and consider introducing the same fields from step 1 and 2 above.

If the planet is close enough to the star, the corona may be affected in shape or intensity.



Step 4: Fields in the environment: Search the list of fields below for fields that exist or can be added permanently or temporarily into the environment. Can changes in the parameter that you would like to measure change these fields in any way?

Other large objects wobble due to the gravitational attraction of the planet. The star maintains a thermal field and gives off light. Detect the wobble by a slight Doppler shift of light coming from the star.

Example—Detecting Corrosion

How can corrosion be detected on metallic corrosion samples

Step 1 Internal Fields: Search this list of fields for one that already inhabits or can inhabit the bulk of the subject. Once the subject has this added field, how does it manifest itself outside of the measured object? We can allow for some of these fields to exist momentarily or they may require a constant source.

A thermal field can inhabit the corrosion. The emission of infrared from the field may be how the corrosion is detected and measured.

Step 2 Surface Fields: Search this list of fields for ones that is already attached or can be permanently or temporarily attached to the subject. Once the subject surface has this added field, how does it manifest itself away from the surface? We can allow for some of these fields to exist momentarily or they may require a constant source.

Skin current is probably the most applicable field. The skin current can be measured as an impedance at multiple frequencies.

Step 3 Fields in or on attached objects: Attach objects or identify already attached objects and consider introducing the same fields from step 1 and 2 above.

No solution is found.

Step 4: Fields in the environment: Search the list of fields below for fields that exist or can be added permanently or temporarily into the environment. Can changes in the parameter that you would like to measure change these fields in any way?

No solution is found.

L3-(Potential Phenomena)—Substance Markers

This method can be used to measure the main parameter or any of the secondary phenomena that we have identified. Having addressed field markers, we now consider substance markers. A substance marker is an additive or existing substance which reacts to a paired field in such a way that it is easily detectable. A "Paired" field is one that is uniquely matched with the substance in such a way that it reacts very strongly to it. As an example, magnetic substances react strongly to magnetic fields. Like field markers, substance markers allow for the detection of existence of a substance or field which then allows other parameters to be measured.

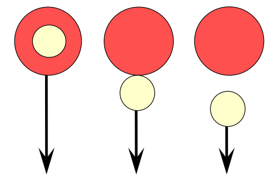
Let's look at the refrigerant leak example which will be given later. Refrigerant leaks are difficult to detect because once the refrigerant leaks to the atmosphere, the refrigerant vaporizes. Most refrigerants also carry a small amount of lubricating oil for the compressor and this can be detected if a lot of refrigerant escapes. Wouldn't it be easier if the refrigerant flashed a neon sign, so to speak, to announce its location? The use of markers almost creates a neon sign. If a luminescent substance which is compatible with the refrigerant and oil is introduced into the coolant loop, any refrigerant that escapes also leaves behind some of this luminescent material which is easily detected with an ultraviolet light. The process was to, first, introduce a luminescent substance marker into the refrigerant. Next, introduce a field which is strongly paired with the luminescent substance. The luminescent substance marker then gives off another field, light, which is easily detected by the human eye. Once we can detect the refrigerant, we can employ further means to measure its attributes.

Note that substance markers are different than field markers. In the case of field markers, we added a field to the substances of the system and then detected the manifestation of that field as the measured parameters changed. The introduction of a field is more ideal since no substance has to be added. However, if substances which strongly react to fields are already present in the system then the use of substance markers can be very ideal. The tan box gives other ways to make the addition of markers more ideal. Consider these ways to produce additives that come close to not existing.[36]

- Especially active or concentrated additives (very little is needed)
- Temporary additive (eliminated or self eliminated when not needed.)
- Decomposition of native materials (use only the part that delivers the function. It can be chemically decomposed or segmented)

36 STANDARD 4-2-4. If it is impossible to introduce easily detectable additives in the external environment, these can be obtained in the environment itself, for instance, by decomposing the environment or by changing the aggregate state of the environment. Notes: In particular, gas or vapor bubbles produced by electrolysis, cavitation or by any other method may often be used as additives obtained by decomposing the external environment. Example: The speed of a water flow in a pipe might be measured by amount of air bubbles resulting from cavitation.

Internal, Attached and Detached Markers



An internal marker is a substance additive that is mixed with or nested in the subject. This substance interacts with a matching field to aid detection. [37] An attached marker is a marker which sits on the outside of the subject. This may be done to avoid the contamination or because it does not easily mix with the subject. A detached marker may be necessary if interaction with the subject and marker must be kept to a minimum. In this case, a secondary effect which the subject has upon the environment is detected.[38] Remember that the ideal additive is one that does not exist.

Method

Step 1: Does the subject or anything which is always attached to the subject react strongly with any of the fields in the Table of Fields. If so, then consider using this substance as the marker before introducing any new substances. The field that reacts strongly can be used to make the substance detectable.

Elastic Stress	Gravity	Friction	Adhesion			
Buoyant Force	Hydrostatic Pressure	Jet Pressure	Surface Tension			
Centrifugal Force	Inertial Force	Coriolis Force				
Oder & Taste	Diffusion	Osmosis	Chemical Fields			
Sound	Vibrations & Oscillations	Ultrasound	Waves			
Thermal Heating or Cooling	Thermal Shocks	Information				
Corona Discharge	Current	Eddie Currents	Particle Beams	Nuclear Forces		
Electrostatic Fields	Magnetic Fields	Electromagnetic Fields				
Radio Waves	Micro Waves	Infrared	Visible Light	Ultraviolet	X-Ray	Cosmic

Step 2: If not, then introduce a substance marker in/onto the subject or into/onto attached objects. Following is a list of fields and paired substances. Give greater consideration to the fields that already exist in the parameters being measured. This allows us to avoid adding new fields.

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37 STANDARD 4-2-2. If a system (or its part) does not provide detection or measurement, the problem is solved by transition to an internal or external complex measuring SFM, introducing easily detectable additives. Example: To detect leakage in a refrigerator, a cooling agent is mixed with a luminescent powder.

38 STANDARD 4-2-3. If a system is difficult to detect or to measure at a given moment of time, and it is not allowed or not possible to introduce additives into the object, then additives that create an easily detectable and measurable field should be introduced in the external environment. Changing the state of the environment will indicate the state of the object. Example: To detect wearing of a rotating metal disc contacting with another disk, it is proposed to introduce luminescent powder into the oil lubricant, which already exists in the system. Metal particles collecting in the oil will reduce luminosity of the oil.

- Elastic Stress: stress paint, carbon paper, carriers in germanium and silicon, high creep materials, Ferro-electrics
- Gravity: liquids, high density substances, ion channels, mammalian cells, plant roots, endothelial cells, stem cells, lymphocytes, myocytes
- Friction: carbon paper,
- Adhesion: paired adhesives, easily fragmented materials, powders
- Buoyant Force: inflatable structures, bubbles, weights
- Hydrostatic Pressure / Jet Pressure: bubbles, dissolved gasses, visco-plastics, voids, refrigerants
- Surface Tension: Tiny floating objects, thin film structures, bubbles, bubble velocity, capillary structures, liquid adhesion/cohesion, micro-fluidic devices, inks, paint, coatings
- Centrifugal / Inertial Force / Coriolis Force: low viscosity liquids, flyweights, shock sensors, springs, certain living cells, halteres structure of insects, biological structures in birds
- Oder / Taste / chemical fields: chemical sensing cells in plants and animals such as taste buds or olfactory cells, paired reactive chemicals too numerous to mention.
- Diffusion: gasses with high or low molecular weight, flames
- Osmosis: ions of various sizes, crystalloids, shaped molecules (especially spherically), resin polyesters,
- Sound: small objects, resonant objects such as vibrating wires, super-saturated liquids and solids
- Vibration / Oscillation / Ultrasound / Waves: resonant objects (resonate), Piezo materials (generate voltages), vibration sensitive crystals, low /high viscosity liquids, super-saturated liquids and solids (May coalesce), vapors at sub-critical temperatures (may coalesce), sub-critical temperature solutions (crystallize), magnetic objects (cause voltage changes in electrical loops) nerve tissue (dies), Tanzanite (disintegrates), purified rennin, alkaloids (change color), liquids (ultrasound cavities generate high voltages across them which can be detected), sub-critical temperature solutions (crystallize), buoyant objects
- Thermal Heating or Cooling / Thermal Shocks: state changing materials, certain ceramics, Tanzanite, CaF_2, HCB-18, ZrO_2, cryogenic gases and liquids. dissolved gases.
- Corona Discharge: easily ionized gases
- Current / Eddie currents: Thermo resistant materials, magnetic materials, easily conductive materials, semi conductive materials, super-conductors,
- Particle Beams: luminescent materials, easily ionized materials,
- Nuclear Forces: easily ionized materials, elements with unbalanced charges in the nucleus such as certain isotopes, fissionable materials, fusible materials
- Electrostatic Fields: easily ionized gases, easily charged materials such as sulfur or linen, materials with free charges such as metals, small electro-chargeable objects which repel each other.
- Magnetic Fields: magnetic materials, magnetic powder, super conductors,
- Electromagnetic Fields—Radio Waves—Micro Waves—Infrared—Visible Light—Ultraviolet—X-Ray—Cosmic Radiation: low curie point materials, photo-sensitive materials, easily ionized materials,

Step 3: Identify secondary effects of changing parameters on the existence of substances in the immediate environment. Do these substances have strongly paired fields? Consider using these substances as the markers and then detect and measure the change to these markers.

Step 4: Identify secondary effects of changing parameters on the existence of fields in the environment. Do these field changes have strongly paired substances? Consider adding a substance marker to the environment to make these field changes detectable.

Step 5: Reduce the amount of additive necessary. Consider especially active or concentrated additives (very little is needed). Consider a temporary additive (eliminated *or self eliminated when not needed.) Consider decomposition of native materials (use only the part that delivers the function. It can be chemically decomposed or segmented)*

Example—Detection of Refrigerant Leaks

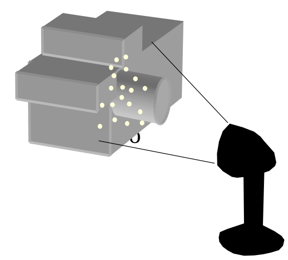
Find a way to detect the leakage of automotive refrigerant.

Step 1: Does the subject or anything which is always attached to the subject react strongly with any of the fields in the Table of Fields. If so, then consider using this substance as the marker before introducing any new substances. The field that reacts strongly can be used to make the substance detectable.

The refrigerant does not react strongly to any of the fields or in a way that is easily detectable.

Step 2: If not, then introduce a substance marker in/onto the subject or into/onto attached objects. Following is a list of fields and paired substances. Give greater consideration to the fields that already exist in the parameters being measured. This allows us to avoid adding new fields.

A luminescent material is introduced into the lubricant. A black light shows the location of the leak.



Step 3: Identify secondary effects of changing parameters on the existence of substances in the immediate environment. Do these substances have strongly paired fields? Consider using these substances as the markers and then detect and measure the change to these markers.

No major secondary effects.

Step 4: Identify secondary effects of changing parameters on the existence of fields in the environment. Do these field changes have strongly paired substances? Consider adding a substance marker to the environment to make these field changes detectable.

One secondary effect is on the chemical fields in the environment. If a strong smelling chemical compound was added to the refrigerant, it might be possible to detect the location by smell.

Step 5: Reduce the amount of additive necessary. Consider especially active or concentrated additives (very little is needed). Consider a temporary additive (eliminated or self eliminated when not needed.) Consider decomposition of native materials (use only the part that delivers the function. It can be chemically decomposed or segmented)

There are a number of highly luminescent materials that were identified by doing an internet search.

Example—Detecting the Movement of Bacteria

How is it possible to detect the movement of bacteria?

Step 1: Does the subject or anything which is always attached to the subject react strongly with any of the fields in the Table of Fields. If so, then consider using this substance as the marker before introducing any new substances. The field that reacts strongly can be used to make the substance detectable.

The bacteria react to diffusion, but not in a detectable manner. Something needs to make the bacteria detectable.

Step 2: If not, then introduce a substance marker in/onto the subject or into/onto attached objects. Following is a list of fields and paired substances. Give greater consideration to the fields that already exist in the parameters being measured. This allows us to avoid adding new fields.

No Solution is found.

Step 3: Identify secondary effects of changing parameters on the existence of substances in the immediate environment. Do these substances have strongly paired fields? Consider using these substances as the markers and then detect and measure the change to these markers.

The movement of the bacteria leaves waste products in the environment. The medium is modified to react with the waste products to make the bacteria visible. Since the waste products are different for each type of bacteria, it would be necessary to adjust the chemical markers which are added to the environment.

Step 4: Identify secondary effects of changing parameters on the existence of fields in the environment. Do these field changes have strongly paired substances? Consider adding a substance marker to the environment to make these field changes detectable.

The presence of bacteria does not largely change any fields in the environment.

Step 5: Reduce the amount of additive necessary. Consider especially active or concentrated additives (very little is needed). Consider a temporary additive (eliminated or self eliminated when not needed.) Consider decomposition of native materials (use only the part that delivers the function. It can be chemically decomposed or segmented)

It would be preferable to have a substance which does not affect the bacteria or their movement.

Example—Detecting Corrosion

We would like to detect the presence of corrosion.

Step 1: Does the subject or anything which is always attached to the subject react strongly with any of the fields in the Table of Fields. If so, then consider using this substance as the marker before introducing any new substances. The field that reacts strongly can be used to make the substance detectable.

The corrosion reacts strongly to electrical and electromagnetic fields universally. It may also interact with magnetic fields depending on the metal that is being corroded. In these cases, the corrosion, itself, can be the marker.

Step 2: If not, then introduce a substance marker in/onto the subject or into/onto attached objects. Following is a list of fields and paired substances. Give greater consideration to the fields that already exist in the parameters being measured. This allows us to avoid adding new fields.

One paired combination that sticks out is the possibility of introducing isotopes into the materials being tested. If the corrosion is easily removed from the surface then the isotopes would come with it and could be detected by radiographic means.

Step 3: Identify secondary effects of changing parameters on the existence of substances in the immediate environment. Do these substances have strongly paired fields? Consider using these substances as the markers and then detect and measure the change to these markers.

The corrosion does not appear to affect the existence of substances in the immediate environment. No solution is given.

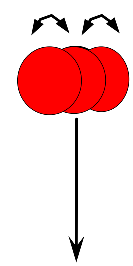
Step 4: Identify secondary effects of changing parameters on the existence of fields in the environment. Do these field changes have strongly paired substances? Consider adding a substance marker to the environment to make these field changes detectable.

The presence of corrosion changes the frequency and amplitude of electromagnetic fields in the environment. It may be possible to use photosensitive materials in the environment tuned to certain frequencies, to detect the corrosion.

Step 5: Reduce the amount of additive necessary. Consider especially active or concentrated additives (very little is needed). Consider a temporary additive (eliminated or self eliminated when not needed.) Consider decomposition of native materials (use only the part that delivers the function. It can be chemically decomposed or segmented)

Due to the decay of isotopes, it may be possible to use very small amounts. Simply expose the samples to high energy neutron radiation to create the isotopes. This could amount to a very small amount of additive.

L3-(Potential Phenomena)—Multiplied Subject Elements



This method can be used to measure the main parameter or any of the secondary phenomena that we have identified. This tool comes from the standards involving multiple system elements.[39] [40] [41] [42]Often, it is easier to detect the average parameter of many objects than it is to detect the properties of a single object. This is almost always true when detecting the properties of small

39 STANDARD 3-1-1. System efficiency at any stage of its evolution can be improved by combining the system with another system (or systems) to form a bi- or poly-system. Notes: For a simple formation of bi- and poly-systems, two and more components are combined. Components to be combined may be substances, fields, substance- field pairs and whole SFMs. Example: To process sides of thin glass plates, several plates are put together to prevent glass from breaking.

40 STANDARD 3-1-2. Efficiency of bi- and poly-systems can be improved by developing links between system elements. Notes: Links between elements of a bi- and poly-system may be made either more rigid or more dynamic. Example: To synchronize a process of lifting a very heavy part by three cranes, it is proposed to use a rigid triangle synchronizing the cranes moving parts.

41 Inventive Principle #7—Nesting (Matrioshka): One object is placed inside another. That object is placed inside a third one. And so on. An object passes through a cavity in another object. Genrich Altshuller, The Innovation Algorithm page 287.

42 STANDARD 3-1-3. Efficiency of bi- and poly-systems can be improved by increasing the difference between system components. The following line of evolution is recommended: similar components (pencils of the same color) –->components with biased characteristics (pencils of different colors) –->different components (set of drawing instruments) –->combinations of the "component + component with opposite function" (pencil with rubber)

things such as particles, molecules, atoms. If you can cause them to interact with each other, it may be possible to amplify effects that you would like to measure.

Method

Step 1: Do the subjects come in natural batches or groups, or are they hard to separate? Is it advantageous to know the average value as opposed to individual values of measurement?

Step 2: Can the subjects be multiplied in a meaningful way?

Step 3: Can these subjects be merged or interact together to create an unexpected capability? Try different orientations.

Example—Measuring the Temperature of an Insect

How can the temperature of small insects be measured for the purpose of establishing their metabolic rate?

Step 1: Do the subjects come in natural batches or groups, or are they hard to separate? Is it advantageous to know the average value as opposed to individual values of measurement?

It is advantageous to know the average value as opposed to the individual values

Step 2: Can the subjects be multiplied in a meaningful way?

Yes, they can be gathered into a group of insects.

Step 3: Can these subjects be merged or interact together to create an unexpected capability? Try different orientations.

Measuring the insects as a group makes it easier and gives an average value which may be more ideal in some situations.

Example—Measuring Corrosion

How can the corrosion of a metallic sample be measured?

Step 1: Do the subjects come in natural batches or groups, or are they hard to separate? Is it advantageous to know the average value as opposed to individual values of measurement?

The corrosion first occurs in pockets or areas across the metal specimen. They come as a group but they are already separated. It is advantageous to know the average value of the corrosion.

Step 2: Can the subjects be multiplied in a meaningful way?

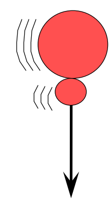
They are already multiplied. Multiplying samples is a possibility but this would be accomplished by segmenting the sample. One advantage of this is that this would result in an increase of the surface area (corrodible area) substantially. Such a segmented sample would need to be in constant electrical contact with the corresponding electrode (usually the cathode). This could be accomplished by scattering the segmented metal across a non-conductive surface. If the particles were sufficiently small, then the corrosion rate could be measured by the time taken to corrode the particles sufficiently to break all electrical continuity.

On the other hand, several of the patents used multiple sensors due to the variation in corrosion rate across a surface. One might like to understand the worst rates of corrosion as opposed to the mean corrosion as localized corrosion is what often destroys structures. The average may be small, but localized corrosion can still greatly weaken critical structures. This should probably be kept in mind for the final decision.

Step 3: Can these subjects be merged or interact together to create an unexpected capability? Try different orientations.

It might be possible to get the particles to conduct current from one to the next if they were simply contacting each other within a specified volume. The resulting current, as the particles corroded, would be an indication of the corrosion rate.

L3-(Potential Phenomena)—Resonance



This method can be used to measure the main parameter or any of the secondary phenomena that we have identified. Resonance[43] is an important type of secondary parameter. Many parameters can be measured by the resonance of an object or an attached object[44]. Virtually every field can be detected by resonance. (Thermal resonance is difficult to achieve). It can occur at all levels from macro objects to particles to molecules to atoms to electrons. It may be necessary to induce oscillations into the subject in order to measure the resonant frequency.[45]

Method

Step 1: Identify if there is a natural resonance in the system for any of the following types of field resonance: Mechanical Vibration, Sound, Fluid Surface Waves, Electrical Resonance, Particle States, Electromagnetic Oscillation, Nuclear Resonance.

Step 2: If the resonance is weak, are there ways to boost the resonance such that a change in the measured parameter affects the resonance? Consider attaching an object and measuring the resonant amplitude, frequency or decay rate of oscillation.

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43 Inventive Principle #18—Mechanical Vibration: Utilize oscillation. If oscillation exists, increase its frequency to ultrasonic. Use the frequency of resonance. Replace mechanical vibrations with Piezo-vibrations. Use ultrasonic vibrations in conjunction with an electromagnetic field. Genrich Altshuller, The Innovation Algorithm page 288.

44 STANDARD 4-3-3. If resonance oscillations may not be excited in a system, its state can be determined by a change in the natural frequency of the object (external environment) connected with the system. Example: The mass of boiling liquid can be measured by measuring the natural frequency of gas resulting from evaporation.

45 STANDARD 4-3-2. If it is impossible to detect or measure directly the changes in the system, and no field can be passed through the system, the problem can be solved by exciting resonance oscillations (of the entire system or of its part), whose frequency change is an indication of the changes taking place. Example: To measure the mass of a substance in a container, the container is subjected to mechanically forced resonance oscillations. The frequency of the oscillations depends on the mass of the system.

Example—Measurement of Resistance in a Wire and Its Connections

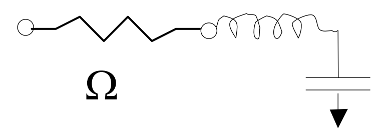
Step 1: Identify if there is a natural resonance in the system for any of the following types of field resonance: Mechanical Vibration, Sound, Fluid Surface Waves, Electrical Resonance, Particle States, Electromagnetic Oscillation, Nuclear Resonance.

All electrical systems have resonance.

Step 2: If the resonance is weak, are there ways to boost the resonance such that a change in the measured parameter affects the resonance? Consider attaching an object and measuring the resonant amplitude, frequency or decay rate of oscillation.

A capacitor and inductor can be added in series. A change in resistance will affect how rapidly the resonance decays.

Resistance changes current resonance



Example—Measurement of Corrosion

Step 1: Identify if there is a natural resonance in the system for any of the following types of field resonance: Mechanical Vibration, Sound, Fluid Surface Waves, Electrical Resonance, Particle States, Electromagnetic Oscillation, Nuclear Resonance.

Since high frequency electrical current travels in the upper layers of a conductor, the effect of corrosion should create a large change in the impedance of the surface current. This, in turn, should create a detectable change in the resonant frequencies of these surface currents.

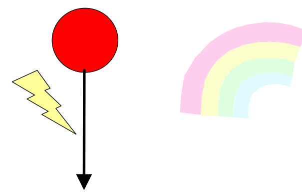
Step 2: If the resonance is weak, are there ways to boost the resonance such that a change in the measured parameter affects the resonance? Consider attaching an object and measuring the resonant amplitude, frequency or decay rate of oscillation.

Inductors and capacitors can be added to boost the resonance of the circuit.

L3-(Potential Phenomena)—Natural Analogous Observer

Nature has developed many analogous phenomena that can be employed to perform functions. Along with naturally occurring physical phenomena, there are also biological phenomena that all for the performing of functions. When biological functions are used, this is referred to as bio-mimicry[46]. Identifying objects in nature that require the same function will begin to lead the seeker to new physical phenomena.

Natural Product = ?



Method

Step 1: Start with the required change of properties of the observer due to a change of properties of the object being measured.

Step 2: State this in short format.

Step 3: Where does this transformation occur in nature?

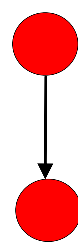
Step 4: Transfer this feature to the new situation. Consider combining this with the existing observer or transferring the minimum amount of the observer.

Example—Voltage Change Due to Temperature Change of Hydrogen Gas

How can the temperature of hydrogen gas be measured in a new way?

Step 1: Start with the required change of properties of the observer due to a change of properties of the object being measured.

The voltage of the observer object must change due to a temperature change of the gas.



Step 2: State this in short format.

Temperature changes voltage. (T→V)

Step 3: Where does this transformation occur in nature?

Large amounts of charge are gathered during storms due, in part, to convection in clouds.

Step 4: Transfer this feature to the new situation. Consider combining this with the existing observer or transferring the minimum amount of the observer.

Temperature variation causes movement of the gas which interacts with charged moisture, inducing a voltage in objects nearby.

46 Otto Schmitt, is credited with creating the term bio-mimicry.

L3-(Potential Phenomena)—Library of Scientific Effects

This method can be used to measure the main parameter or any of the secondary phenomena that we have identified. Normally, the Library of Effects is a table of physical phenomena that can be used to deliver functions. However, in the case of informing functions, the library is used in a different manner. We simply go to the measurement section and look for new ways to measure a parameter. In some cases of informing functions, it is good to strip away some of the technical jargon. For instance, if we were trying to detect byproducts of corrosion, we might not use the term rust, but rather porous materials. In other cases, we need to keep the technical terms.

Method

Step 1: Convert the given informing function to a generalized informing function. If a resource filter is available then filter for the fields and the substances.

Step 2: Find phenomena in the Library of Scientific Effects. Some commercial software have this library. A scaled-down version can be found at: http://function.creax.com/

Example—Measurement of Corrosion Rate

By this point, we have collected a long list of possible ways to detect and measure corrosion.

- Electrical Resistance (Patents)
- Linear Polarization (Patents)
- Galvanic current (Patents)
- Measure back scatter of beta nuclear radiation (Patents)
- Measure the rate of decay of the potential of the electric double layer (Patents)
- Alternating current impedance (Patents)
- Low frequency noise voltage (Patents)
- MRI (Patents)
- Infrared radiation reflection (Patents)
- Magnetometer measures magnetic fields (Patents)
- Digital imaging (Patents/ products)
- Corrode through multitude elements (Patents)
- Ultrasound (Patents)
- Structural shape of the surface (New)
- Fractal dimension of surface (New)
- Number of active sites (New)
- Interaction site surface area (New)
- Change in coupon weight (Patents)
- Number of voids (New)
- Porosity (New)
- Activity of sites (New)
- Coupon thickness (Patents)
- Height above original surface (Patents)
- Coupon Volume (Inferred from patents)
- Surface density (New)
- Surface Molecular Weight (New)
- Surface Thermal Conductivity (New)
- Surface Thermal Capacity (New)
- Surface Magnetic Permeability (New)
- Surface Magnetic Hysteresis (New)
- Surface Curie Point (New)
- Surface DC impedance (New)
- Surface AC impedance (Inferred from Patents)
- Surface electrical continuity (New)
- Surface Ionization Potential (New)
- Surface Electric Permittivity (New)
- Optical reflectivity (Inferred from Patents)
- Optical emissivity (New)
- Optical absorption (New)
- Optical scattering (New)
- Fringe pattern of reflected light (Patents)
- Difference in digital images (Products)
- Emission from thermal field (New)
- Impedance of skin current (Implied from Products)
- Loss of Isotope (New)
- Photosensitive materials tuned to certain frequencies (New)
- Scatter particles across a non-conductive surface--measure time to loss of continuity (New)
- Resonance of surface currents (New)

Note that many of these are new and we do not know how to measure the change in the given parameter. Each one of these secondary parameters could lead us to new methods of measuring corrosion. For the sake of brevity, we will pick one of these to show how it is done. Let us pick measurement of porosity as an example and see what the library of Scientific Effects can show us.

Step 1: Convert the given informing function to a generalized informing function. If a resource filter is available then filter for the fields and the substances.

The generalized function is the measurement of porosity. In this case, the technical jargon has to remain.

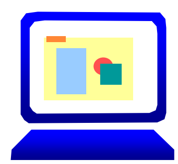
Step 2: Find phenomena in the Library of Scientific Effects. Some commercial software versions have this library. A scaled-down version can be found at: http://function.creax.com/

The scientific effect of evaporation from a porous surface is suggested. A fixed volatile liquid is introduced into a porous surface and allowed to evaporate. The temperature achieved is a function of the surface area of the surface which is an indication of porosity. In performing this process, it was discovered that the library of scientific effects that was used distinguishes between "detecting" and "measuring". "Measuring" comes under parameter measurement. Detecting can refer to substances or fields which are separated in the table.

L3-(Potential Phenomena)—Search Patents

Why Search for Patents Now?

One of the best times for performing a patent search is when you are searching for physical phenomena to deliver a function for the following reasons.



6,543,345

5,678,432

3,234,211

First, you may be able to identify potential physical phenomena that you can use to deliver the measurement that you are seeking.

Second, there is a wealth of information in patents. You can learn about problems with the phenomena and how they are overcome. Patents are structured so that others can duplicate the results of an invention. Consequently, it is necessary to give away many details. Lots of additional information is learned along the way that strengthens our general understanding of the physics. Understanding a broad spectrum of physical phenomena will make you a better inventor! Where we get into trouble is by studying only certain areas of physics deeply. Remaining "specialists" can have a constraining effect on our imagination.

Third, patents complete the chain of transformations from the measurement to the final observer. Usually, you will have a variety of potential circuits or other phenomena. In fact, this body of patents involving circuits is usually quite large since there may be a variety of devices that could be used, each having their advantages. Many of these circuits can be copied, especially if the patents are expired. If you add something unique to the circuit, you may be able to patent it.

Fourth, patent searches give us an idea of technology we might be excluded from. Since there will be so many ways to get around this technology, why run the risk of violating someone's patent?

Fifth, patent searches give us an idea of the weaknesses of existing patents which prepare us to know how we might develop and present our invention to exclude others.

Don’t Wait Too Long

Most people wait too long in the inventive process to perform a patent search. Typically, people wait until much time and expense have gone into developing their invention. Often they find that someone has already patented their idea or that more useful and elegant concepts are available. This can be quite a blow! Waiting too long occurs for a variety of reasons.

First, people get excited about an idea and they want to develop it without delay. They think that there is no time to waste! The idea must be put on the market before someone steals it or you lose your drive! This fear is usually unfounded. Be patient, there are many inventions to be had if this one doesn’t pan out.

Secondly, considering a patent search can invoke fear. It is like knowing that you should see the doctor while fearing that he will give you bad news. It is easy to this put off, but, like going to the doctor, the time investment is small compared to the time that can be wasted by not acting. You might use a few days to do a thorough patent search which is a small investment compared to the typical development time for an invention. Even though the resulting information can be somewhat deflating, it is better to start with a realistic view.

Thirdly, a patent search can appear to be beyond our capabilities. After all, people are employed full time to do patent searches! Again, this fear is unfounded. It is important to remember that you have several advantages that professional patent searchers do not have. You are motivated by the prospects of your idea. (A patent examiner is employed for money and is obligated to perform to certain minimum standards). You are not constrained by time and can afford to search to the bitter end. (Not all patent examiners are thorough and there may be time constraints on some examiners). You are more familiar with the technology than they are. (They do not have the time to become expert at the technologies that you are interested in). With a little practice, this overwhelming task can become natural and commonplace.

Fourth, understanding patents is difficult. Admittedly, patent attorneys have their own language. In this language, there is no legal prohibition to making up words! Patents can seem very stiff and…legal. Remember that it is in the favor of the legal profession that they look this way. We can easily convince ourselves that only patent attorneys can read patents. On the contrary, anyone can thoroughly understand a patent if they are willing to take the time. They have a repeatable structure, so you can learn the parts of the patent that you need to go to for specific information. Remember that it is much easier to learn to read patents when you are motivated by an idea. This will force you into the patent. Read it, digest it, and diagram it. Soon, you will be speaking “patenteze”. Reading and understanding your first patent may take you a half day, but the next patent will go much faster.

Fifth, some feel that seeing what others have done will keep them from looking “outside the box”. Sure, there is a possibility that this can temporarily happen, but remember that these books are about making us uncomfortable inside the box. There are multiple opportunities to kick ourselves outside.

It is ok that you do not understand everything about patents when you begin your search. True, like first time car drivers, it is impossible to know what you do not know, but you have to start somewhere. If you make mistakes, remember that there is a world of potential inventions out there. Dive in and you will find that you have more capacity than you thought!

The Structure of Patents

Most patents begin with a description of the typical approaches that are already available. This sets the stage for why their idea is an improvement. It usually gives the history of the problem (and sometimes the industry) and also a look at alternative physical phenomena that have been used. Following the history is a description of the invention and why it is an improvement. This gives details into new physical phenomena that may have been used. It may describe how various object attributes affect the operation of the product. You may also be able to detect how the inventor overcame various contradictions. Clearly articulating the contradiction that was solved helps an inventor explain why their invention is "non-obvious to those experienced in the art". This is the main hurdle that is required to get a patent. Next is a detailed description of the architecture of the invention. This gives valuable clues concerning the details of the physics. Finally, the claims section gives an idea to the scope of what the patent examiner thought was allowable to claim for the invention.

Preparing for Patent Searching

Most of what you need can be accomplished by using Google patent search . You can search for patents; look at specific patents and view patent drawings. Viewing the drawings is particularly important as it conveys a lot of information quickly. A patent summary is usually given as the first search result. It should take less than an hour to set yourself up on a computer to do your first patent search. Here is how to setup your computer browser with the necessary bookmarks to do a basic patent search:

Step 1: Go to www.uspto.gov. This is the official patent website for the US government. If you take the time to familiarize yourself with this site, you will discover that a lot of effort has been made to make patent search and application easier for individuals. All of the forms are available for self application. There seems to be a bias towards helping individuals over corporations. You will particularly notice this if you submit a patent for consideration (this is called prosecuting a patent). People at the patent office sometimes bend over backward to help individuals, especially ones that have never been through the process before.

Step 2: Bookmark the definition of classifications and give it a memorable name. It is located at: http://www.uspto.gov/web/patents/classification/selectnumwithtitle.htm. Each patent is assigned a patent classification. Having a link to the classifications helps the searcher delineate between classifications. When you get to this page, you will notice that there is a numbering system which starts with items such as "apparel". Remember that this is a very old system of classifying patents that was based upon products that were available when it was started. Scroll down this list and look for more modern classifications to appear. Click on any one of the definitions. This will take you to sub-classifications. Patents are usually assigned a classification and at least one sub-classification. When you select one of the classification numbers, you finally arrive at the definitions.

Step 3: Bookmark the index of classifications and give it a memorable name. It is located at: http://www.uspto.gov/web/patents/classification/uspcindex/indextouspc.htm. When you have an invention with a common name, you can find the classification by going to this index. Everything is listed in alphabetical order. For instance, if you are working on an improvement for hand shovels, you can go to shovels and find that there are a variety of objects which are referred to as shovels. There are hand shovels, power shovels, crane shovels, loading shovels, plow shovels, etc. This is important to know because many of these systems provide exactly the same function as the one that you are considering. In effect, they provide analogous functions in different industries. It is possible that they use physical phenomena and lines of evolution that are different from your industry. These can be put to work in your situation. Also, when you later identify other analogous products, you can readily find the patents for these products by using this index.

Method

Step 1: Determine whether there is a need for patent searching. Do you need to identify potential physical phenomena that you can use to deliver the measurement that you are seeking? Do you need to understand the phenomenon more deeply? Do you need the chain of circuits back to the observer? Do you need an idea of technologies you might be excluded from? Do you need an idea of the weaknesses of existing patents so you can develop and present your invention to exclude other?

Step 2: Using the Google patent search feature, search for a patent directly related to the parameters and/or the secondary parameters that you are trying to measure.

Step 3: Identify the classification(s).

Step 4: Use the Google search using the classification that makes the most sense. Add anything that can further narrow down to the best patents

Step 5: View all patents that this patent references. Identify those that apply and then look at their references. Ignoring the references that you have seen before, concentrate on the new references and whether they apply. Continue this process until no new patents regarding your area of interest show up.

Step 6: Note the other electronic or other elements in the system that allow the measurement of the parameter to be changed to a voltage, current or other satisfactory means of measurement.

Example—Measurement of Corrosion Rate

When the Library of Scientific Effects were demonstrated, we summarized a long list of parameters that could be measured to give a measurement of corrosion. We could search patents for any of these methods and then relate it to how we might measure corrosion rate. This time, let's look at how electric permittivity might be measured by searching patents.

Step 1: Determine whether there is a need for patent searching. Do you need to identify potential physical phenomena that you can use to deliver the measurement that you are seeking? Do you need to understand the phenomenon more deeply? Do you need the chain of circuits back to the observer? Do you need an idea of technologies you might be excluded from? Do you need an idea of the weaknesses of existing patents so you can develop and present your invention to exclude other?

The answer to all of the questions is "yes".

Step 2: Using the Google patent search feature, search for a patent directly related to the parameters and/or the secondary parameters that you are trying to measure.

Using the Google patent search feature we found patent US54815690 titled "Apparatus and methods for measuring permittivity in materials." This patent provides a method for measuring the permittivity of curing polymers. Multiple flat electrodes are laid against the material being measured. Each electrode couples to the next electrode through the material by fringing fields. By changing which electrodes are activated, different spacing occurs which affects the effective capacitance between each antenna. By imposing alternating voltage signals on the antenna and then measuring the current response, it is possible to determine the "capacitance" of each configuration. A permittivity is then calculated for the material at various depths. We note that the subject matter of this patent is directly related to the function of measuring corrosion that we would like to perform. One characteristic is the ability to measure the permittivity at different depths. Further, measuring at different periods of time allow for the measurement of corrosion rate.

Step 3: Identify the classification(s).

When we look at this patent, we discover that the classification used is 324/674; 324/634; 324/661; 324/687; 340/870.37 Using the class number & titles link we discover that 324 (which relates to three of the classifications) is called "electricity: measuring and testing" this is a very broad classification and likely covers all measurements of permittivity. Classification 340 relates specifically to "communications: electrical" Using this will make our search too narrow. So, for the moment, let's concentrate on 324. Since there are several subclasses for 324, we need to look carefully for the one that is closest to what we are looking for. This is not to say that the others will not apply, it is just that the closest one is a better starting point for the search. By making use of the definitions of classifications and the index of classifications, the closest classification is 324/663: Subclass 663 relates to 600 IMPEDANCE, ADMITTANCE OR OTHER QUANTITIES REPRESENTATIVE OF ELECTRICAL STIMULUS/RESPONSE RELATIONSHIPS (1 dot) 649 Lumped parameters (2 dots) 658 Using capacitive type measurement (3 dots) 663 Where a material or object forms part of the dielectric being measured. Since corrosion forms part of the dielectric being measured, this is a specific classification that relates to what we are trying to measure.

Step 4: Use the Google search using the classification that makes the most sense. Add anything that can further narrow down to the best patents

I added the search parameter "corrosion" by performing the Google patent search for "324/663 corrosion". This yielded the following very interesting patent which is even more in line with what we are looking for. This is a good starting patent: US4481616—Scanning Capacitance Microscope. In this invention, a very small conductive tip scans across a substrate which is conductive, covered by a substance, such as corrosion. Since the corrosion has a different permittivity than the substrate, this shows up as a difference in capacitance between the conductive probe and the conductive substrate. The probe scans across a surface and senses changes in capacitance which may be interpreted as defects, corrosion, etc.

Step 5: View all patents that this patent references. Identify those that apply and then look at their references. Ignoring the references that you have seen before, concentrate on the new references and whether they apply. Continue this process until no new patents regarding your area of interest show up.

This process was followed allowing the patent history to go before the time when previous references were not required in new patents, (circa 1946). The first references that the author found were in 1932. Following that, all references were searched for references that applied. The new references were likewise searched. Due to popularity of using capacitance sensing to measure the property of substances between the electrodes, there were more patents than could be included in this text. An Excel file was kept of patents that applied and those that didn't. This allowed for interleaving new patents and checking for new patents. Both patents that applied and patents that did not apply need to be noted to avoid rereading patents that you have already looked at. Below is a representation of patents that seemed to apply.

US1878109—20-Sep-32—Means for determining the moisture content and quality of materials—Uses capacitive change of a material to measure the moisture content. It recognizes that the materials may vary and thereby change the capacitance of an oscillating circuit. This patent uses vacuum tubes. It has no previous references.

US2043241—9-Jun-36—Apparatus for determining the moisture content of a material—It uses capacitive change of a material to measure the moisture content of grains. It recognizes that the materials may vary and thereby change the capacitance of an oscillating circuit. It also uses vacuum tubes. It has no previous references.

US2076441—U6-Apr-37—Moisture tester and method—Uses capacitive change of a material to measure the moisture content of grains. It recognizes that the materials may vary and thereby change the capacitance of an oscillating circuit. It also uses vacuum tubes. It has no previous references.

US2222221—19-Nov-40—Method and apparatus for testing steel strip thickness—It uses capacitive change of a material to measure the thickness of metal straps. It recognizes that the materials may vary and thereby change the capacitance of an oscillating circuit. It also uses vacuum tubes and a Piezo crystal. It creates a resonant circuit with high oscillating current. As the capacitance changes, it drives the response away from the resonant frequency and the amplitude of the current drops very rapidly. It has no previous references.

US2251641—5-Aug-41—Apparatus for Testing Materials—Moisture content is measured by using both capacitance and resistance. It uses vacuum tubes. It has no previous references.

US2266114—16-Dec-41—Moisture determining apparatus—Uses capacitive change of a material to measure the moisture content of grains. It recognizes that the materials may vary and thereby change the capacitance of an oscillating circuit. It also uses vacuum tubes. It has no previous references.

US2373846—17-Apr-45—Method and apparatus for moisture measurement of materials.—This attacks the problem of conductance in the dielectric. Even though the plates may not be conducting, charge is moving back and forth across the dielectric due to the conductivity of the material. This might be important in our situation as there may be some conductivity in the corrosion. It has no previous references.

US2399582—30-Apr-46—Electrical Inspection and Sorting—Uses capacitance to measure changes. It has no Previous References.

US2422742—24-Jun-47—Meter for measuring moisture—Uses capacitive change of a material to measure the moisture content of grains. It recognizes that the materials may vary and thereby change the capacitance of an oscillating circuit. Also uses vacuum tubes. This patent has many References. All following patents have several references that were checked for applicability.

US2529846—14-Nov-50—Zero Suppression system for electronic moisture register instruments—Side by side plates are used to measure the moisture of wood, etc. As the moisture in the circuit increases, the Power absorbed increases. This patent uses vacuum tubes.

US2535027—26-Dec-50—Apparatus for measuring and controlling moisture content or the like—Uses the change in series resistance of the capacitors and the change in capacitance to reveal moisture content and then make changes to the production process.

US2562575—31-Jul-51—Electronic Device for Measuring Physical Constants—It measures the capacitance of objects. It introduces a crystal oscillator of known frequency but which can be changed slightly.

US2772394—27-Nov-56—Devices for finding protruding metal objects in shoes—A capacitor probe is extended on a handle into a shoe. The capacitance of the probe changes very sharply while near a protruding metal object. It does not react strongly to non-protruding objects. It uses vacuum tubes. It is interesting that this probe reacts so strongly to protruding metal objects even though they do not protrude through the probe.

US2948850—9-Aug-60—Apparatus for analyzing weight composition of materials—This patent seeks to measure the moisture content and the dry weight separately by using the resonant frequency and the amplitude of the tank circuit signal.

US3122956—3-Mar-64—Apparatus for detecting and removing defective sections of advancing textile material—This is primarily a capacitance measuring circuit which uses transistors instead of vacuum tubes. The schematics might give some good ideas on how to actually measure the capacitance of the corrosion. What is shown here is not really ground-breaking.

US3764899—1973—Apparatus for measuring variations in thin plastic films—plastic film threaded between electrodes. It is capable of measuring thickness variations to 5 millionths of an inch

US3815021—1974—Two Threshold level detector using a capacitive or inductive probe for sorting—It sorts objects on a conveyor belt using capacitance and a bridge circuit.

US4481616—6-Nov-84—Scanning Capacitance Microscope—This is the patent that was noted in the beginning which is probably the closest thing to what I am looking for.

Step 6: Note the other electronic or other elements in the system that allow the measurement of the parameter to be changed to a voltage, current or other satisfactory means of measurement.

Patents are one of the best ways to find good ways to convert a measurement to a voltage or current. Many circuits were discovered, too numerous to show here. Since most of these patents have expired, this is a treasure trove of good ideas that can be used with your invention. Some of these ways can be repackaged in your invention.

L3-(Potential Phenomena)—Intelligent Little People

There may be steps in the chain that we do not know how to accomplish. In effect, we need to discover a new way to deliver an informing function. This is truly a synthesis of a new idea. One of the most important tools of investigation is empathy. This is the ability to become a part of the system that we are investigating and to see it from this unique perspective. The principle of empathy is very powerful, but has some limitations. First, we provide only one perspective from which to view the problem. Secondly, we must exist in order to view the problem. In other words, we cannot dissolve or disappear. Third, there is just one of us to interact with the system. If there were more of us to interact, this would open up new possibilities. These difficulties are largely overcome by using the principle of intelligent little people[47].

Method

Step 1: Envision the system as composed of intelligent little people who can work together. These people also have the capability to disappear and reappear if necessary. What do they do to accomplish the desired result? How do they intelligently act together?

Step 2: Consider possible physical phenomena that can accomplish this cooperation.

47 Creativity as an Exact Science-The Theory of the Solution of Inventive Problems by G.S. Altshuller. Gordon and Breach page 104

Example—Corrosion Measurement

I order to show how this works, we need to pick something that we have no idea how to do. Looking back on the physical phenomena that change with corrosion, we pick number of active corrosion sites. Before we go on, we need to assume that there are a finite number of sites across the surface of the sample which are above some threshold area. What we would like to do is to know the number of sites. How can intelligent little people help us?

Step 1: Envision the system as composed of intelligent little people who can work together. These people also have the capability to disappear and reappear if necessary. What do they do to accomplish the desired result? How do they intelligently act together?

We imagine a line of little people linking arms and crossing the sample together. Whenever one of the little people looks down and sees a corrosion site, she yells out to one of the little people on the side line who takes note. Once the line of little people are across the sample, a final tally is taken.

Step 2: Consider possible physical phenomena that can accomplish this cooperation.

This reminds the author of how a digital scanner works. It might be possible to scan a sample, looking for corrosion points that reflect a certain color of light. Each pixel is then counted for the number of corrosion sites.

L3-(Potential Phenomena)—Summarize the Potential Phenomena

Here, we simply summarize the potential phenomena that we have considered in the previous steps.

Method

Summarize the phenomena from the previous steps

Example—Corrosion Measurement

Summarize the phenomena from the previous steps

- Electrical Resistance (Patents)
- Linear Polarization (Patents)
- Galvanic current (Patents)
- Measure back scatter of beta nuclear radiation (Patents)
- Measure the rate of decay of the potential of the electric double layer (Patents)
- Alternating current impedance (Patents)
- Low frequency noise voltage (Patents)
- MRI (Patents)
- Infrared radiation reflection (Patents)
- Magnetometer measures magnetic fields (Patents)
- Digital imaging (Patents/ products)
- Corrode through multitude elements (Patents)
- Ultrasound (Patents)
- Structural shape of the surface (New)

- Fractal dimension of surface (New)
- Number of active sites (New)
- Interaction site surface area (New)
- Change in coupon weight (Patents)
- Number of voids (New)
- Porosity (New)
- Activity of sites (New)
- Coupon thickness (Patents)
- Height above original surface (Patents)
- Coupon Volume (Inferred from patents)
- Surface density (New)
- Surface Molecular Weight (New)
- Surface Thermal Conductivity (New)
- Surface Thermal Capacity (New)
- Surface Magnetic Permeability (New)
- Surface Magnetic Hysteresis (New)
- Surface Curie Point (New)
- Surface DC impedance (New)
- Surface AC impedance (Inferred from Patents)
- Surface electrical continuity (New)
- Surface Ionization Potential (New)
- Surface Electric Permittivity (New)
- Optical reflectivity (Inferred from Patents)
- Optical emissivity (New)
- Optical absorption (New)
- Optical scattering (New)
- Fringe pattern of reflected light (Patents)
- Difference in digital images (Products)
- Emission from thermal field (New)
- Impedance of skin current (Implied from Products)
- Loss of Isotope (New)
- Photosensitive materials tuned to certain frequencies (New)
- Scatter particles across a non-conductive surface--measure time to loss of continuity (New)
- Resonance of surface currents (Existing Products)
- Measure porosity by evaporation temperature (Library of Effects)
- Capacitance change of the surface (Patents)
- Capacitance from oscillating circuit (Patents)
- Capacitance plus resistance of the corrosion (Patents)
- Capacitance using side-by-side sensing plates (Patents)
- Resonance of corrosion (Patents)
- Scanning Capacitance Microscope (Patents)

L2-Observer Resources

Let's review what we have just done. Once we decided what the ideal measurement was, we looked for POTENTIAL physical phenomena. We haven't chosen any of them. We have sensitized ourselves to the possible ways to perform the measurement. Unfortunately, it is still not the time to determine how we are going to perform the measurement because we need to look at the POTENTIAL ways that we could use to deliver the physical phenomena. We would like to sensitize ourselves to the various ways that we might deliver the phenomena, especially with the minimum use of system resources. There is less freedom to use existing resources with informing functions because there is the additional requirement that a final observer has already been established. The measurement system has to link into this final observer. In the case of more general useful functions, we do not have to meet this requirement. Whatever exists in the environment or system is fair game to deliver the functions.

L2-Method

Step 1: Are there abundant native fields that could be used to perform the function?

Step 2: Make a list of nearby elements that could be enlisted to perform the function.

Step 3: Make a list of cheap abundant substances in the environment or in the system that could be used.

Step 4: Identify measuring devices in the system or environment that could be used in the measurement chain.

Step 5: Consider using a copy of the current measurement device which requires only a portion of the original system.

Step 6: If there are measurement devices in the super-system, then consider merging with it in order to take advantage of these devices.

L3-Abundant Native Fields

Most objects are awash in native fields[48]. These fields do not remain constant throughout the product life cycle. By identifying the fields all around the observer, we locate observer resources that can perform the function.

Elastic Stress	Gravity	Friction	Adhesion			
Buoyant Force	Hydrostatic Pressure	Jet Pressure	Surface Tension			
Centrifugal Force	Inertial Force	Coriolis Force				
Oder & Taste	Diffusion	Osmosis	Chemical Fields			
Sound	Vibrations & Oscillations	Ultrasound	Waves			
Thermal Heating or Cooling	Thermal Shocks	Information				
Corona Discharge	Current	Eddie Currents	Particle Beams	Nuclear Forces		
Electrostatic Fields	Magnetic Fields	Electromagnetic Fields				
Radio Waves	Micro Waves	Infrared	Visible Light	Ultraviolet	X-Ray	Cosmic

Method

Step 1: Process Map the product life through relevant life stages.

Step 2: Look through the Table of Fields and identify which native fields the subject experiences at each process step. Which of these native fields perform this function even poorly?

Step 3: Can any of these fields be used in the potential physical phenomena that we have identified?

48 STANDARD 5-2-1. If a field has to be introduced in a SFM, one should use first of all the present fields for whom the media are those substances that form the system or its part. Note: The use of substances and fields which already present in the system improves the system's ideality: number of functions performed by the system increases without increasing the number of used components.

STANDARD 5-2-2. If a field has to be introduced in a SFM and it is not possible to use the fields which already present in the system, one should use the fields of the external environment. Note: The use of external environment fields (gravitation, thermal field, pressure...) improves the system's ideality: the number of functions performed by the system increases without increasing the number of used components.

STANDARD 5-2-3. If a field has to be introduced in a SFM but it is impossible to use the fields which already present in the system or in the external environment, one should use the fields for whom the substances present in the system or external environment can act as media or sources. Notes: In particular, if there are ferromagnetic substances in a system and they are used for mechanical purposes, it is possible to use their magnetic properties in order to obtain additional effects: improve interactions between components, obtain information on the state of the system, etc.

Example—Corrosion Measurement

We have been considering corrosion by the use of capacitive load. Is it possible that native fields are already at play?

Step 1: Process Map the product life through relevant life stages.

Sample Preparation→Mounting in Container→Mounting Electrodes →Introduction of Acid→Introduction of Voltage

Step 2: Look through the Table of Fields and identify which native fields the subject experiences at each process step. Which of these native fields perform this function even poorly?

Gravity, Buoyant Force, Sound, Waves, Thermal Fields, Ambient Electromagnetic Fields, Light

Step 3: Can any of these fields be used in the potential physical phenomena that we have identified?

It is possible that the weak electromagnetic fields and the light (also an electromagnetic field) might be used.

L3-Grocery List of Adjacent Elements

In this step we consider ordinary elements about us that might be pressed into service[49] to deliver the required physical phenomena. This method is especially effective with low level fields such as elastic fields, gravity, pressure, etc.

Method

Step 1: Make a laundry list of adjacent elements, especially those which were not considered in the super-system functional models.

Step 2: Consider decomposing elements into new components.

Step 3: What fields are associated with these objects?

Step 4: Consider ways in which elements on the list might be pressed into service to perform the required modification.

Example—Corrosion Measurement

We will now ask ourselves what resources are nearby that we might use.

Step 1: Make a laundry list of adjacent elements, especially those which were not considered in the super-system functional models.

49 Inventive Principle #6—Universality: an object can perform several different functions ; therefore, other elements can be removed. Genrich Altshuller, The Innovation Algorithm page 287.

Since we are already in a testing environment, there are likely resources that could be used: Compressed air, ovens, microscopes, weight scales, electrical power supplies, multi-meters, micrometers, ultrasonic cleaning devices, water, vacuum, intense light used in microscopes and oscilloscopes.

Step 2: Consider decomposing elements into new components.

The water could be decomposed to hydrogen and oxygen. The air could be decomposed into its basic elements of nitrogen, oxygen, carbon-dioxide and other less common gasses.

Step 3: What fields are associated with these objects?

Neglecting the measuring devices, the compressed air has pressure and dynamic pressure fields. The ovens have thermal fields. The ultrasonic cleaners have ultrasound. The vacuum sources have pressure. The water sources could provide buoyancy and pressure fields. The oxygen and hydrogen could be combined to create intense energy.

Step 4: Consider ways in which elements on the list might be pressed into service to perform the required modification.

The ovens could still be used to speed up reactions, even if they are taken more rapidly.

L3-Grocery List of Cheap Abundant Substances

When a function can be delivered at low cost, the value of the system increases. If there is a way to use a cheap abundant substance, try to use it. If the phenomenon is weak, it may be possible to boost the phenomenon later.

Method

Consider the following list of cheap substances. Could any of these be used to deliver any of the phenomena that you are considering? List of Cheap Substances: Powders— Foams— Voids— Water— Ice— Steam— Hydrates— Air— Nitrogen— Carbon Dioxide— Oxygen— Corrosion— Decay— Sand— Soil— Rocks— Waste— Waste Water— Sawdust— Waste Glass— Waste Gases— Waste Paper— Garbage— Yard Waste— Industrial Wastes— Hybrid Substances— Disassociated Forms of Any of the Above— Products of Interactions— Starting Materials— Final Products— Semi-Finished Elements

Example—Corrosion Measurement

What simple and cheap substances could be used? We could consider using the following:

- Micro-voids could be purposely introduced to induce high rates of local corrosion
- Water is already available and used
- Steam is readily available and could be used to accelerate corrosion
- Pure oxygen could be introduced to increase the rate of corrosion

L3-Nearby Similar Measurement Devices

Depending on how systems evolve, it is common that several elements in the system need detection or measurement. Several objects may be detected or measured by the same observer[50]. Sometimes, this same observer can be pressed into service to perform the function on both subjects.

Method

Step 1: Identify a similar observer nearby which detects or measures similar attributes.

Step 2: Combine and consolidate[51] both elements into one system.

Example—Corrosion Measurement

Since we are in a testing laboratory environment, there are many measurement devices nearby.

Step 1: Identify a similar observer nearby which detects or measures similar attributes.

The measuring devices that are closest to what we need are dynamic systems analyzers which are used to identify systems by stimulating them with random input signals and monitoring their outputs. The Fast Fourier Transform algorithms give a frequency response of the test system. Such a measurement device could be used with the capacitive sensing that we have been considering. It could also be used to look at skin currents and other parameters that we have considered here.

Other nearby measuring instruments that might be employed are digital multi-meters.

Step 2: Combine and consolidate[52] both elements into one system.

The dynamic systems analyzer could be readily used as the output device for any system that outputs voltage, impedance or current as a function of the parameter that is measured. In this case, the output that is measured is the impedance as a function of the frequency.

50 Inventive Principle #6—Universality: an object can perform several different functions ; therefore, other elements can be removed. Genrich Altshuller, The Innovation Algorithm page 287.

51 Inventive Principle #5—Consolidation: Consolidate in space homogeneous objects, or objects destined for contiguous operations. Consolidate in time homogeneous or contiguous operations. Genrich Altshuller, The Innovation Algorithm page 287.

52 Inventive Principle #5—Consolidation: Consolidate in space homogeneous objects, or objects destined for contiguous operations. Consolidate in time homogeneous or contiguous operations. Genrich Altshuller, The Innovation Algorithm page 287.

L3-Simplified Copy of the Current Measurement Device

Use of the current observer can be overkill, especially if the observer is a human. A simplified copy[53] can often perform the same function as the full observer.

Method

Step 1: What part of the current observer performs the function?

Step 2: Can a copy of the observer perform the function?

Example—Corrosion Measurement

Since we are not interested in performing the measurement function with the current method of weighing the sample before and after corrosion, this method does not apply.

L3-Merge with the Super-System

Sometimes, it is the most advantageous to give up functions of the system and turn them over to the super-system. Note that this is an exception to the rule that the slave must not serve the master. There are some conditions where integration yields much higher performance than modularity.

Method

Step 1: Look for functions performed in the super-system that are identical with functions performed in the system.

Step 2: Transfer these functions to the super-system.

Example—Corrosion Measurement

The current measurement super-system is the laboratory environment, or the select instruments that would be used for corrosion testing. Some devices might be pressed into service and become part of the corrosion measurement system.

Step 1: Look for functions performed in the super-system that are identical with functions performed in the system.

Heating the samples in acid require both the acid that is used in the incumbent system and the ovens.

Step 2: Transfer these functions to the super-system.

Heating of the sample in the existing acid is definitely transferred to the new system. This appears to be an obvious result, however.

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53 Inventive Principle #26—Copying: A simplified and inexpensive copy should be used in place of a fragile original or an object that is inconvenient to operate. If a visible optical copy is used, replace it with an infrared or ultraviolet copies. Replace an object (or system of objects) with their optical image. The image can then be reduced or enlarged. Genrich Altshuller, The Innovation Algorithm page 288.

L3-Summarize the Observer Resources

Here we simply summarize what we have already learned.

Method

Summarize the substance and field resources from the previous steps.

Example—Corrosion Measurement

Summarize the substance and field resources from the previous steps.

- Weak electromagnetic fields present in the corrosion process
- Light (also an electromagnetic field) might be used.
- Compressed air
- Ovens
- Microscopes
- Weight scales
- Electrical power supplies
- Multi-meters
- Micrometers
- Ultrasonic cleaning devices
- Water
- Vacuum
- Intense light used in microscopes.
- Micro-voids could be purposely introduced to induce high rates of local corrosion
- Steam is readily available and could be used to accelerate corrosion
- Pure oxygen could be introduced to increase the rate of corrosion
- The dynamic systems analyzer
- Acid from the current system

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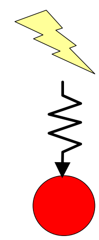
L2-Ideal Observer

In choosing the ideal tools to perform the function, there are a number of considerations to keep in mind. We would like the tool to be as ideal as possible, but what does this usually mean? In this section, we look at ways to tell if a tool is more ideal. We do this with an understanding that all tools will bring burdens for the system. We just want the lowest burden possible.

Abundance

The availability or abundance of resources to deliver the physical phenomena must be high. Objects and resources are already present in the environment that can help deliver the physical phenomena. We do not determine in this section whether a sufficient abundance exists. This will occur in the next section. That is why this section deals with possible physical phenomena.

Self-Service

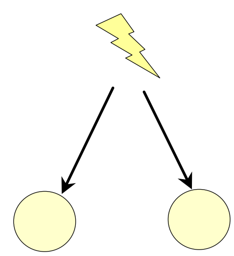


One thing that abundance facilitates is the possibility of self-service. If possible, we would like to add no elements to the system. If possible, the function should exist but no objects and substances should be added. "Self-service" is one way to achieve this. Sometimes, this is accomplished by native fields in the environment or the system.

Inherent Harm (Contact)

Some tools, with their attending physical phenomena require the addition of harmful interactions. This is especially true with physical phenomena that require contact. If physical phenomena are present which do not require contact and the resources for providing this physical phenomena are abundant, then consider these over those that require contact.

Multiple Functions including Passive Control and the Anti-Function



A more ideal physical phenomenon is capable of performing multiple functions. The value of objects in a system is dependent upon two things, the number of useful functions that they deliver and the burdens that they create. In this case, we are considering the number of functions that they deliver. It is only possible to consider multiple functions if other functions in the system are already required. There is no reason to create functions to perform in order to allow a physical phenomenon to perform more functions. The secondary function that the phenomenon performs may be a supporting function but more ideally, it should be a primary function that acts directly on the system product.

In the case of measurement, it would be more ideal if the physical phenomenon could both sense and control. If sensing and actuation are required in the same system, then it is ideal to perform both functions with the same subject. It is therefore necessary that the physical phenomenon is capable of delivering both.

The evolution of systems predicts that systems will eventually take on the anti-function in order to provide more value. The anti-function is often provided by the super-system already, but it is often forgotten because it may occur much later than when the product or process is applied. But what does this mean when we refer to measurement? Whenever measurement occurs, there is a disturbance to the system. If you dip a thermometer into a hot liquid, the liquid must change the temperature of the thermometer in order for it to register. For every action, there is an equal and opposite reaction. While the thermometer is being heated, the liquid is being cooled. While most measuring instruments are designed to disturb the system as little as possible, a very accurate measurement of the system may require that the disturbance be undone, preferably at the same time that the measurement is taken.

Scalable

A more ideal physical phenomenon is capable of being scaled to the level necessary to meet increasing and decreasing demands.

Relative Risk

When we move to a new phenomenon to deliver a function, we are taking upon ourselves unknown risks. Therefore it is important to come to an understanding of this new phenomenon as rapidly as possible and make sure that the risks are localized to one or two major risks.

Allow for the Measurement to be undone—avoid Destructive Testing

Some measurement requires the disturbance of the system or even the destruction of the system. Typical destructive testing often requires the loss of the element that is being measured. This would be an extreme form of contact. We would like to avoid destructive testing if possible. If a disturbance must occur, we would like it to be reversible.

L2-Method

Step 1: Try to identify the most ideal observer possible from the viewpoint of use of abundant resources, its ability to scale and the avoidance of destructive testing.

Step 2: Consider commercially available measurement systems.

Step 3: Consider using any known disruptive technologies. If they exist, then consider using a hybrid of the existing method and the disruptive technology.

Step 4: Decide what the measuring system will be.

L3-Filter for the Ideal Observer

The ideal observer has many characteristics. We may not be able to achieve all of them, but the more that are satisfied, the more ideal the observer becomes.

Method

We have looked at so many different ways that we could measure corrosion. Some of these we developed to show the utility of different approaches. Here, we will look deeper to see which of the methods might be more ideal. Following is a list of the possible methods that we have looked at so far. We get this from the summary of Physical Phenomena.

- Electrical Resistance (Patents)
- Linear Polarization (Patents)
- Galvanic current (Patents)
- Measure back scatter of beta nuclear radiation (Patents)
- Measure the rate of decay of the potential of the electric double layer (Patents)
- Alternating current impedance (Patents)
- Low frequency noise voltage (Patents)
- MRI (Patents)

- Infrared radiation reflection (Patents)
- Magnetometer measures magnetic fields (Patents)
- Digital imaging (Patents/ products)
- Corrode through multitude elements (Patents)
- Ultrasound (Patents)
- Structural shape of the surface (New)
- Fractal dimension of surface (New)
- Number of active sites (New)
- Interaction site surface area (New)
- Change in coupon weight (Patents)
- Number of voids (New)
- Porosity (New)
- Activity of sites (New)
- Coupon thickness (Patents)
- Height above original surface (Patents)
- Coupon Volume (Inferred from patents)
- Surface density (New)
- Surface Molecular Weight (New)
- Surface Thermal Conductivity (New)
- Surface Thermal Capacity (New)
- Surface Magnetic Permeability (New)
- Surface Magnetic Hysteresis (New)
- Surface Curie Point (New)
- Surface DC impedance (New)
- Surface AC impedance (Inferred from Patents)
- Surface electrical continuity (New)
- Surface Ionization Potential (New)
- Surface Electric Permittivity (New)
- Optical reflectivity (Inferred from Patents)
- Optical emissivity (New)
- Optical absorption (New)
- Optical scattering (New)
- Fringe pattern of reflected light (Patents)
- Difference in digital images (Products)
- Emission from thermal field (New)
- Impedance of skin current (Implied from Products)
- Loss of Isotope (New)
- Photosensitive materials tuned to certain frequencies (New)
- Scatter particles across a non-conductive surface--measure time to loss of continuity (New)
- Resonance of surface currents (Existing Products)
- Measure porosity by evaporation temperature (Library of Effects)
- Capacitance change of the surface (Patents)
- Capacitance from oscillating circuit (Patents)
- Capacitance plus resistance of the corrosion (Patents)
- Capacitance using side-by-side sensing plates (Patents)
- Resonance of corrosion (Patents)
- Scanning Capacitance Microscope (Patents)

Step 1: Abundance: In order for the physical phenomenon to have any chance, it should be abundant in the system. Summarize the potential phenomena to allow only those which have abundant resources.

Step 2: Self Service: Can one of the human senses directly detect the needed observation?

Step 3: Does the physical phenomenon allow the disturbance of measurement to be undone? Does it avoid destructive testing?

Step 4: Scalable: Is the physical phenomenon capable of being scaled to larger or smaller scales?

Step 5: Familiarity and Localization of Risk: Become as familiar with the phenomenon as rapidly as possible to determine the inherent problems and risks. The drawbacks should be localized to one or two areas.

Example—Corrosion Measurement

We have looked at so many different ways that we could measure corrosion. Some of these we developed to show the utility of different approaches. Here, we will look deeper to see which of the methods might be more ideal. Following is a list of the possible methods that we have looked at so far. We get this from the summary of Physical Phenomena.

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- Interaction site surface area (New)
- Change in coupon weight (Patents)
- Number of voids (New)
- Porosity (New)
- Activity of sites (New)
- Coupon thickness (Patents)
- Height above original surface (Patents)
- Coupon Volume (Inferred from patents)
- Surface density (New)
- Surface Molecular Weight (New)
- Surface Thermal Conductivity (New)
- Surface Thermal Capacity (New)
- Surface Magnetic Permeability (New)
- Surface Magnetic Hysteresis (New)
- Surface Curie Point (New)
- Surface DC impedance (New)
- Surface AC impedance (Inferred from Patents)

- Surface electrical continuity (New)
- Surface Ionization Potential (New)
- Surface Electric Permittivity (New)
- Optical reflectivity (Inferred from Patents)
- Optical emissivity (New)
- Optical absorption (New)
- Optical scattering (New)
- Fringe pattern of reflected light (Patents)
- Difference in digital images (Products)
- Emission from thermal field (New)
- Impedance of skin current (Implied from Products)
- Loss of Isotope (New)
- Photosensitive materials tuned to certain frequencies (New)
- Scatter particles across a non-conductive surface--measure time to loss of continuity (New)
- Resonance of surface currents (Existing Products)
- Measure porosity by evaporation temperature (Library of Effects)
- Capacitance change of the surface (Patents)
- Capacitance from oscillating circuit (Patents)
- Capacitance plus resistance of the corrosion (Patents)
- Capacitance using side-by-side sensing plates (Patents)
- Resonance of corrosion (Patents)
- Scanning Capacitance Microscope (Patents)

Step 1: Abundance: In order for the physical phenomenon to have any chance, it should be abundant in the system. Summarize the potential phenomena to allow only those which have abundant resources.

We have already considered which fields and substances are abundant when we considered observer resources in the previous section. For this example, let's only consider equipment that would be in a typical laboratory.

- Weak electromagnetic fields present in the corrosion process
- Light (also an electromagnetic field) might be used.
- Compressed air
- Ovens
- Microscopes
- Weight scales
- Electrical power supplies
- Multi-meters
- Micrometers
- Oscilloscope
- Ultrasonic cleaning devices
- Water
- Vacuum
- Intense light used in microscopes.
- Micro-voids could be purposely introduced to induce high rates of local corrosion
- Steam is readily available and could be used to accelerate corrosion
- Pure oxygen could be introduced to increase the rate of corrosion
- Acid from the current system

Now, let's only include those phenomena which have abundant resources in the laboratory setting. Some of these can be combined.

- Measure the rate of decay of the potential of the electric double layer (Oscilloscope)
- Surface impedance (Oscilloscope or Multi-meter for DC components)

- Resonance of corrosion (Patents)
-
- Linear Polarization (Multi-meter, oscilloscope)
- Galvanic current (Multi-meter, oscilloscope)
- Low frequency noise voltage (Oscilloscope)
-
- Digital imaging (High Res. Digital Camera)
- Number of active sites (Microscope)
- Interaction site surface area (Microscope)
- Number of voids (Microscope)
-
- Activity of sites (bubble or volume of bubbles formed)
-
- Coupon dimensions (Micrometer)
-
- Change in coupon weight (Scales)
-
- Measure porosity by evaporation temperature (thermocouples, stop watch)

Step 2: Self Service: Can one of the human senses directly detect the needed observation?

In this case, the level of corrosion would be directly observable and quantifiable simply by smelling, hearing, feeling or seeing the sample. Probably the closest to this would be to observe the corrosion directly through a microscope and count the active sites or bubbles.

Step 3: Does the physical phenomenon allow the disturbance of measurement to be undone? Does it avoid destructive testing?

The only phenomenon that includes destructive testing is the one that allows corrosion to occur enough to destroy the coupon. This is probably not a big deal since the coupon is meant to be destroyed. On the other hand, the corrosion testing can be conducted on articles in production or in-service without the need to create a coupon. This may be useful in some situations.

Step 4: Scalable: Is the physical phenomenon capable of being scaled to larger or smaller scales?

The phenomena that can be scaled from very large to very small are:

- Linear Polarization (Multi-meter, oscilloscope)
- Low frequency noise voltage (Oscilloscope)

Step 5: Familiarity and Localization of Risk: Become as familiar with the phenomenon as rapidly as possible to determine the inherent problems and risks. The drawbacks should be localized to one or two areas.

Most of the drawback of linear polarization have been resolved due to length of time this has been in service.

The problems of low-frequency noise voltage are mostly minor and related to algorithms that look at the statistical parameters of the noise to give an indication of corrosion level.

L3-Commercial Measurement Systems and Subsystems

This step addresses two actions that we need at this point. First, it allows us to confirm whether products exist in the marketplace that performs the required function and secondly, we want to know what systems and subsystems are available to help us create prototypes and potentially products.

Need for a Commercial Product Search

While it may seem that we have covered our bases of commerciality when we did the patent search, actually we have not. It is easy to believe that patents represent all products. Unfortunately, most inventions are not patented and most patents are never commercialized. Consequently, we need to go beyond patents and perform searches of commercial products if we want to be sure. On the other hand, our first product and literature searches may have been sufficient to cover the bases.

Looking for Subsystems and Components

At this point, we may also have the need to identify system and subsystem elements that we can use to deliver the phenomenon. It makes little sense to build components from scratch if they can already be inexpensively purchased. This goes along with looking for inexpensive prototyping materials. We might find that entire systems exist that have components that we need. Sometimes these can be inexpensively purchased through on-line auctions and dismantled for the pieces.

Method

Step 1: Is the commercial product search adequate for our needs or do we need to identify systems and subsystems from which we can build prototypes? Do we need to do another search?

Step 2: Use an internet search-engine to find existing products and services. Refine the search by noting and using nomenclature and names that are common to the industry.

Step3: If products exist, find places that you can go to examine and purchase the hardware.

Example—Corrosion Measurement

Since we have identified that we can measure corrosion using capacitance, Let's continue to look for commercial components that might be used to build parts of the prototype and eventually the components themselves.

Step 1: Is the commercial product search adequate for our needs or do we need to identify systems and subsystems from which we can build prototypes? Do we need to do another search?

We really need to identify capacitive sensing components that could be used to sense capacitance. From the foregoing search, it appears that we have covered the bases for capacitive type corrosion monitoring. However, we will still check to make sure and then go on to look for existing systems that sense capacitance to determine other object parameters. Perhaps we can use existing systems to measure corrosion.

Step 2: Use an internet search-engine to find existing products and services. Refine the search by noting and using nomenclature and names that are common to the industry.

Capacitive sensors have been used to monitor corrosion in steel reinforced concrete structures.[54] The principle works in a different way than imagined before. The capacitors is buried in the concrete next to the steel specimen and then driven by an oscillating signal. The impedance of the capacitor changes as a function of the levels of ions in the materials. The level of the ions in the concrete indicate the level of corrosion. It is not entirely clear, to the author, how this happens unless it is due to slight charge separations that occur close to the capacitor and effectively change the impedance of the capacitor.

Step3: If products exist, find places that you can go to examine and purchase the hardware.

54 Embedded capacitor sensor for monitoring corrosion of reinforcement in concrete—Sitifatimah Abul Rahman, Mohammad Ismail, Norhazilan Md Noor, Hazribakhitiar

L3-Use Known Disruptive Technology

In this step, we will consider the direct migration to a disruptive technology. As mentioned in our historical consideration of disruptive technologies, a direct adoption of a disruptive technology can be very disruptive to our own business. A progressive business may want to do this if they think that it will also be disruptive to their main competitors, but there are important considerations.

First, this strategy may require destructive creation of products In order to disrupt existing competition, you will ultimately cannibalize yourself. If your customers begin to buy the new product, they must also stop buying your legacy product.

Second, the adoption of disruptive technologies often require the creation of new business models, usually in completely separate business units than your legacy products.

Third, disruptive technology will need to compete against your biggest customers for resources. Your biggest customers are only happy if their products come to them without interruption. When resources are diverted to new technologies, this interrupts the flow to them. Most decision makers will opt in favor of the biggest customers drawing the resources away from the new disruptive technology.

Fourth, adopting disruptive technologies often require the change of long-held company values at the highest levels of the business. It is hard to admit that your business strategy and company values are wrong. In order to make this kind of change a lot of people have to be aligned and committed. If they are not convinced, they will likely revolt in passive ways that are hard to detect and counter.

For this reason, it is usually best to create disruptive technologies is with new business startups. The new business will create its own business model and supply chain from scratch. In order to work, the resources need to be separate from the main business in order to avoid competition.

Another way to get into the disruptive technology is to develop the technology in an adjacent market so that you don’t have to cannibalize yourself. If you pick a non-consuming market the need to compete is virtually eliminated.

Method

Step 1: Identify technologies that exist in adjacent markets that seem to be threatening the existing business. These may be low cost alternatives or alternatives that use a different physical phenomenon to deliver the function.

If we consider the disruption of standard coupon testing to be the incumbent technology in the laboratory, then electro-chemical means of detecting corrosion would be the disruptive technology.

Step 2: Identify the physical phenomenon that is used to deliver the function. It is likely that this will later be considered for a hybrid physical phenomenon to satisfy the target market.

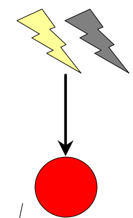
Of the electrochemical means that are currently in use in adjacent markets, the following probably apply:

- Surface impedance (Oscilloscope or Multi-meter for DC components)
- Linear Polarization (Multi-meter, oscilloscope)

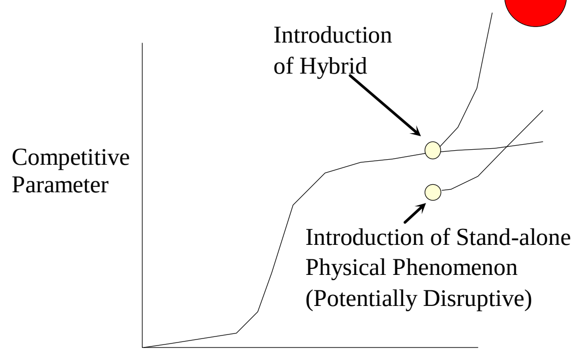
L3-Hybrid Combination of Physical Phenomena

The reason for considering this step here is that others may be encroaching on your market and it is necessary to consider the physical phenomena that this disruptive technology is using. We do this because there is a way out of this trap and that is hybrid phenomena. Hybrid phenomena are the combination of two phenomena in such a way that the performance gained by one phenomenon compliments the other. In this way, the new phenomena can be used to better satisfy the existing market. This would be difficult to do if we made a sudden jump to the new phenomenon. When this occurs the performance is usually less than what the existing market expects. According to evolution of systems, when we move between physical phenomena, there is usually a transitional state through hybrid phenomena. A recent example of this is hybrid electric and petrol fueled vehicles.

Trying to satisfy an entrenched sustaining market will be unlikely with a completely new physical phenomenon as some very important competitive parameter will almost certainly be compromised. The sustaining market will demand that we not depart from the performance that they are used to, although the s-curve of performance is flattening. New markets will be much more forgiving and may even welcome the weaknesses of the new physical phenomenon as strength.



The new Phenomenon will gather strength as a hybrid and eventually replace the old phenomenon or it will gather strength as a stand-alone phenomenon in the new market. Clayton Christensen[55] points out, it is possible that the new stand-alone phenomenon will develop along its own s-curve and eventually become a disruptive technology, taking away market share from the existing sustaining markets. Also, if the existing phenomenon is in the rapid growth part of the S-Curve, it will be difficult to catch up. Greater resources will keep the performance ahead of the new phenomena.



Instead of jumping to the new phenomena entirely, it is possible to gain the rapidly developing advantages of the new phenomena or technology by creating a hybrid[56] of the new and old phenomenon. This tool if extremely useful when you are working with a demanding sustaining market and the resources of the current phenomenon are becoming limited. This is a way to move to the new physical phenomena while increasing (rather than sacrificing) performance, as is often the case when jumping to a new effect.

Method

Step 1: Begin with a common physical phenomenon that is normally used to deliver the modification.

Step 2: Identify another phenomenon (especially if it is disruptive) which performs the same modification.

55 The Innovator's Dilemma by Clayton M. Christensen—Harper Business Essentials

56 STANDARD 3-1-3. Efficiency of bi- and poly-systems can be improved by increasing the difference between system components. The following line of evolution is recommended: similar components (pencils of the same color) –->components with biased characteristics (pencils of different colors) –->different components (set of drawing instruments) –->combinations of the "component + component with opposite function" (pencil with rubber)

Step 3: What is the feature of the second new phenomenon which would extend the capability of the second new phenomenon?

Step 4: Identify the cheap part of the observer which should deliver most of the function.

Step 5: Combine both phenomena into a hybrid. A new capability should emerge. Try combining both as whole subjects. Try transferring just the desirable feature. Consider having the two physical phenomena interact with each other.

Example—Corrosion Testing

Step 1: Begin with a common physical phenomenon that is normally used to deliver the modification.

Weight loss from coupons.

Step 2: Identify another phenomenon (especially if it is disruptive) which performs the same modification.

The second disruptive phenomenon is electro-chemical corrosion testing.

Step 3: What is the feature of the second new phenomenon which would extend the capability of the second new phenomenon?

The feature is the ability to ability to measure the corrosion at any point and potentially stop the test after the first few minutes. This allows for screening of samples instead of performing the whole test, only to determine that the material was completely out of the question for the given application.

Step 4: Identify the cheap part of the observer which should deliver most of the function.

When it comes to testing, fast is cheap. In this case, the electro-chemical method would be the cheapest.

Step 5: Combine both phenomena into a hybrid. A new capability should emerge. Try combining both as whole subjects. Try transferring just the desirable feature. Consider having the two physical phenomena interact with each other.

The combination of coupon testing and electro-chemical testing is easily accomplished by allowing the coupon to continue corroding as long as necessary to establish a stable rate of corrosion. (We would expect that the initial measurements would not be stable, but rather move asymptotically to a corrosion level). When the test is stopped, the sample can undergo the standard examination for weight loss, perhaps with a very sensitive scale used to weigh before and after results.

L3-Decide the Measurement System

Wow, there is a lot of possibilities to choose from. If you have followed the steps, then you have a lot of information that can be used to make the decision. But, a decision it is. There are no automatic decisions. Some of the information that you have generated would tend to lead in opposing directions.

Method

Decide what you are going to do.

Example—Corrosion Testing

Decide what you are going to do.

The decision is to go with a combination of electro-chemical testing and coupon testing. One of the important factors that influence this is that from the laboratory testing point of view, electro-chemical testing is a truly disruptive technology. Industrial standard societies have shown the viability of this testing in the laboratory setting. It is quick and the equipment used to perform it is not particularly expensive. There is extensive use in the adjacent industry of corrosion monitoring. Putting a lot of resources into developing one of the other technologies will likely not be effective because the money is going into electro-chemical testing. It is difficult to compete against rapidly improving technologies that are attracting money. Using a hybrid technology allows us to continue to reassure the customer that the testing results are valid and rapidly screen poor candidates.